PSA/2007/2

Measures of Impact of Science and Technology in India :

Agriculture and Rural Development

M. S. Swaminathan Research Foundation

Office of the Principal Scientific Adviser to the Government of India

सत्यमेव जयते

Measures of Impact of Science and Technology in India: Agriculture and Rural Development

(Measures of Progress of Science and Technology in India - Part III)

MSSRF Research Team

R. Rukmani
(Project Coordinator)

V. Senthilkumar
N. Thenmathi

Consultants

Indumathi M. Nambi
S. John Joseph
Karuna Krishnaswamy
N. Meganathan
M. Prabu
K. N. Selvakumar
A. Serma Saravana Pandian
C. Surendran
K. Susheela

M. S. Swaminathan Research Foundation
Centre for Research on Sustainable Agricultural and Rural Development

Office of the Principal Scientific Adviser to the Government of India

ISBN No. 81-88355-05-4

First Published 2007

Published by :

M. S. Swaminathan Research Foundation
Centre for Research on Sustainable Agricultural and Rural Development
3rd Cross Street, Taramani Institutional Area
Chennai – 600 113
www.mssrf.org

Office of the Principal Scientific Adviser to the Government of India
Vigyan Bhawan Annexe,
Maulana Azad Road
New Delhi-110 011
www.psa.gov.in

CONTENTS

Project Review and Monitoring Committee (PRMC)

Dr. V.L. Chopra (Chairman)

Member Planning Commission, New Delhi

Dr. C.R. Bhatia (Member)

Former Secretary, Department of Biotechnology, Government of India, New Delhi

Dr. Panjab Singh (Member)

Vice Chancellor, Banaras Hindu University, Banaras

Dr. R.P. Gupta (Member-Secretary)

Scientist ‘E’, Office of the Principal Scientific Adviser to the
Government of India, New Delhi

ABBREVIATIONS

ACIAR	Australian Center for International Agricultural Research
AFBC	Atmospheric Fired Bed Combustion
AFC	Agriculture Finance Corporation
AHWR	Advanced Heavy Water Reactor
AI	Artificial Insemination
AICCIP	All India Coordinated Cotton Improvement Project
AICMIP	All India Coordinated Maize Improvement Project
AICORPO	All India Coordinated Research Project on Oilseeds
AICPRP	All India Coordinated Potato Research Project
AICRIP	All India Coordinated Rice Improvement Programme
AICRP	All India Coordinated Research Project
AICRPS	All India Coordinated Research Project on Soybean
AICSIP	All India Coordinated Sorghum Improvement Project
AICWIP	All India Coordinated Wheat Improvement Project
AIDS	Acquired Immuno Deficiency Syndrome
API	Annual Parasitic Index
ARWSP	Accelerated Rural Water Supply Programme
ASMIP	Accelerated Sorghum and Millet Improvement Project
ATIC	Agriculture Technology Information Center

BCG	Bacillus Calmette Guérin
BHEL	Bharat Heavy Electricals Limited
BOBP	Bay of Bengal Programme
BQ	Black Quarter
BSI	Botanical Survey of India
BSP	Breeder Seed Production
BWR	Boiling Water Reactor

CARI	Central Avian Research Institute
CEA	Central Electricity Authority
CGIAR	Consultative Group on International Agriculture Research
CGWB	Central Groundwater Board
CICEF	Central Institute of Coastal Engineering for Fishery
CICR	Central Institute of Cotton Research
CIFA	Central Institute of Freshwater Aquaculture
CIFNET	Central Institute of Fisheries Nautical Engineering & Training
CIFRI	Central Inland Fisheries Research Institute
CIFT	Central Institute of Fisheries Technology
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center)
CIP	International Potato Center
CMFRI	Central Marine Fisheries Research Institute
CMIE	Centre for Monitoring of Indian Economy
CNG	Compressed Natural Gas
CPCB	Central Pollution Control Board
CPRI	Central Potato Research Institute
CRI	Central Research Institute
CRRI	Central Rice Research Institute
CRS	Centre for Rabi Sorghum
CRURRS	Central Rainfed Upland Rice Research Station
CSIR	Council of Scientific & Industrial Research
CSO	Central Statistical Organisation
CSSM	Child Survival and Safe Motherhood Programme
CSWCRTI	Central Soil and Water Conservation Research and Training Institute
CVRC	Central Varietal Release Committee
CWC	Central Water Commission

DALY	Disability Adjusted Life Years
DBCS	District Blindness Control Society
DBT	Department of Biotechnology
DIPA	Dairy Herd Improvement Action
DMI	Drip Method of Irrigation

DMR	Directorate of Maize Research
DOD	Department of Ocean Development
DOTS	Directly Observed Therapy Short course
DPT	Diphtheria Pertussis Tetanus
DRR	Directorate of Rice Research
DST	Department of Science and Technology
DT	Diphtheria Tetanus
DTC	District Tuberculosis Centre
DTH	Down the Hole
DTP	District Tuberculosis Control Programme
DWR	Directorate of Wheat Research
EEZ	Exclusive Economic Zone
EPI	Expanded Programme of Immunisation
ESA	External Support Agencies
ESP	Emission Standard for Particulate Matter
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organization
FARTC	Freshwater Aquaculture Research & Training Centre
FBR	Fast Breeder Reactor
FBTR	Fast Breeder Test Reactor
FFDA	Freshwater Fish farmers Development Agency
FMD	Foot-and-Mouth Disease
FMI	Flood Method of Irrigation
FPC	Forest Protection Committee
FRI	Forest Research Institute
FSI	Fishery Survey of India
GCA	Gross Cropped Area
GDP	Gross Domestic Product
GIS	Geographic Information System
GPR	Ground Penetrating Radar
GPS	Global Positioning System

HIV	Human Immuno Deficiency Virus
HYV	High Yielding Varieties
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICARDA	International Centre for Agricultural Research in Dry Areas
ICCC	Indian Central Cotton Committee
ICDP	Intensive Cattle Development Programme
ICDS	Integrated Child Development Services
ICFRE	Indian Council of Forestry Research and Education
ICMR	Indian Council of Medical Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IEC	Information, Education and Communication
IFFM	Integrated Forest Fire Management
IFGTB	Institute of Forest Genetics and Tree Breeding
IFP	Integrated Fisheries Project
IGCC	Integrated Gas Combined Cycle
IIL	Indian Immunologicals Limited
IISR	Indian Institute of Sugarcane Research
IIT-R	Indian Institute of Technology, Roorkee
IMR	Infant Mortality Rate
INCID	Indian National Committee on Irrigation and Drainage
INP	Indo-Norwegian Project
IOL	Intra-Ocular Lens
IPDP	Intensive Poultry Development Project
IPIRTI	Indian Plywood Industries Research and Training Institute
IREDA	Indian Renewable Energy Development Agency Ltd.
IRR	Internal Rate of Return
IRRI	International Rice Research Institute
IUCN	International Union for Conservation of Nature and Natural Resources
IVRI	Indian Veterinary Research Institute
IWMI	International Water Management Institute

JFM	Joint Forest Management
JSB	Jaswant Singh & Bhattacharya
KFRI	Kerala Forest Research Institute
KJP	Katir Jyoti Programme
KVK	Krishi Vigyan Kendra
KVS	Key Village Scheme
LCU	Leprosy Control Unit
LPG	Liquified Petroleum Gas
MB	Multibacillary
MDT	Multi Drug Therapy
MLEC	Modified Leprosy Elimination Campaign
MLTU	Mobile Leprosy Treatment Unit
MNES	Ministry of Non-Conventional Energy Sources
MoU	Memorandum of Understanding
MPCA	Medicinal Plant Conservation Area
MPEDA	Marine Products Export Development Authority
MPO	Modified Plan of Operation
MSSRF	M.S. Swaminathan Research Foundation
MSY	Maximum Sustainable Yield
NABARD	National Bank of Agriculture and Rural Development
NACO	National AIDS Control Organisation
NAGS	National Active Germplasm Site
NARS	National Agricultural Research System
NBMP	National Biogas Management Programme
NBPGR	National Bureau of Plant Genetic Resources
NCAER	National Council of Applied Economic Research
NDDB	National Dairy Development Board
NDRI	National Dairy Research Institute
NECC	National Egg Coordination Committee

NFAP	National Forestry Action Plan
NGCP	National Goitre Control Programme
NHG	National Sugarcane Hybridization Garden
NICD	National Institute of Communicable Diseases
NIDDCP	National Iodine Deficiency Disorders Control Programme
NIO	National Institute of Oceanography
NLCP	National Leprosy Control Programme
NLEP	National Leprosy Eradication Programme
NMCP	National Malaria Control Programme
NMEP	National Malaria Eradication Programme
NPCB	National Programme for Control of Blindness
NPFSD	National Programme for Fish Seed Development
NRCS	National Research Centre for Sorghum
NRSA	National Remote Sensing Agency
NRWQMSP	National Rural Water Quality Monitoring & Surveillance Programme
NSA	Net Sown Area
NSP	National Seed Project
NSSO	National Sample Survey Organisation
NTCP	National Tuberculosis Control Programme
NWDPRA	National Watershed Development Project for Rainfed Areas
NWFP	Non-Wood Forest Produce

OAE	Own-Account Enterprise
OBC	Other Backward Castes
OF	Operation Flood
ONBS	Open Nucleus Breeding System
OPV	Oral Polio Vaccine
ORS	Oral Rehydration Solution
ORT	Oral Rehydration Therapy

PB	Paucibacillary
PC	Pulverised Coal
PDP	Project Directorate on Poultry
PEM	Protein Energy Malnutrition

PF	*Plasmodium falciparum*
PFBR	Prototype Fast Breeder Reactor
PHWR	Pressurised Heavy Water Reactor
PISFR	Pre-Investment Survey of Forest Resources
PLF	Plant Load Factor
PV	Photovoltaic
QPM	Quality Protein Maize
RCC	Reinforced Cement Concrete
R&D	Research and Development
RE	Rural Electrification
REC	Rural Electrification Corporation
RF	Reserve Forest
RGNDWM	Rajiv Gandhi National Drinking Water Mission
RNTCP	Revised National Tuberculosis Control Programme
RRLRRS	Regional Rainfed Lowland Rice Research Station
SAU	State Agriculture University
SBRI	Sugarcane Breeding & Research Institute
SEB	State Electricity Board
SHP	Small Hydro Power
STD	Sexually Transmitted Disease
TAI	Technology Achievement Index
TB	Tuberculosis
TERI	The Energy Research Institute
TFP	Total Factor Productivity
TMC	Technology Mission on Cotton
TMO	Technology Mission on Oilseeds
TPS	True Potato Seed
TTC	Trainers' Training Centre
TTF	Tiger Task Force
TWAD	Tamil Nadu Water Supply & Drainage Board

UIP	Universal Immunisation Programme
UMMB	Urea Molasses Mineral Block
UNCTAD	United Nations Conference on Trade & Development
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
USDA	United States Department of Agriculture
VLOM	Village Level Operation & Maintenance
WHO	World Health Organisation
WII	Wildlife Institute of India
WUE	Water Use Efficiency
WWF	World Wide Fund for Nature
ZSI	Zoological Survey of India

List of Tables

List of Figures

ACKNOWLEDGEMENTS

Co-ordinating this study has been a wonderful learning experience for me and I am thankful to Professor M.S. Swaminathan for conceiving this study, suggesting a methodology, and providing me this opportunity. His constant motivation and stimulus have helped me immensely.

This study has been funded by the Office of the Principal Scientific Adviser to the Government of India. Dr. R. Chidambaram showed a keen interest in it and participated in the Methodology Workshop as well as in the final meeting of the Project Review Monitoring Committee (PRMC). I owe a special word of thanks to him for his inspiration and support. Dr. V.L. Chopra as Chairman of PRMC and Drs. Panjab Singh, C.R. Bhatia and R.P. Gupta as members of PRMC provided guidance and encouragement all through.

I would like to acknowledge the active help and support extended right through the project period by Dr. P.C. Kesavan, former Executive Director, MSSRF, and Dr. M. Velayutham, our current Executive Director. Drs. V.B. Athreya, J. Jeyaranjan, K. Nagaraj and S. Rajagopalan, apart from being a source of support for me, have provided critical inputs, guidance and valuable comments on my drafts. I am grateful to the Vice Chancellors of Acharya N.G. Ranga Agricultural University, Hyderabad, and Anand Agricultural University, Anand, as well as the Directors of the Indian Council of Agricultural Research Complex, Barapani, and Forest Research Institute, Dehra Dun, for allowing us to hold workshops in their institutions to discuss this report. Several experts have provided extremely useful comments during the course of the study as well as in the Reality Check Workshops held across the country. I would particularly like to thank Dr. S. Ayyappan, Dr.T.N.Balasubramanian, Dr. P. Gomathinayagam, Professor C.H. Hanumantha Rao, Dr. A. Janiah, Dr S. Nagarajan and Dr G.N. Prabhakara for their concrete suggestions.

I owe a deep debt of gratitude to Shri V. Senthilkumar who enthusiastically took on a lot of administrative work related to the project, apart from his academic responsibilities. Drs. Indumathi M. Nambi, S. John Joseph, N. Meganathan, M. Nirmala Devi, M. Prabu, K.N. Selvakumar, C. Surendran, K. Susheela, Ms. N. Thenmathi and Shri Karuna Krishnaswamy ensured that the report was finished on time by sending in their contributions well ahead. Colleagues at MSSRF (particularly from the Library, Accounts and Administration) have been of great assistance. G. Anuradha, R.V. Bhavani, S. Chandra Kala, R. Gopinath, L. Johnson, A. Sakthi Velan and L. Vedavalli have helped in so many different ways and I cherish their friendship.

I acknowledge the help received from Shri S.P. Singh, Under Secretary, Office of the Principal Scientific Adviser to the Government of India. I am thankful to Shri S. Balasundaram, Assistant Postmaster General, Tamil Nadu Circle for providing the inputs for the front cover. Above all, I am grateful to Ms. Gita Gopalkrishnan for her help in editing the report. Last but not the least, I would like to thank Akhil Chandra Associates, New Delhi, for their painstaking efforts towards printing this publication.

R. Rukmani

PREFACE

The UN Millennium Development Goals adopted unanimously by the Members of the UN at the UN Millennium Summit held in 2000 represent a Global Common Minimum Programme for sustainable human well-being and security. The first among these goals relates to reduction in hunger and poverty. Achievement of these goals will depend heavily on the technological and knowledge empowerment of the socially and economically underprivileged sections of the society. Starting with the Industrial Revolution in Europe triggered by the invention of the steam engine in 1780 by James Watt, technology has been an important factor in the rich-poor divide. If technology has enlarged social and gender divides in the past, the challenge now is to enlist technology as an important instrument for achieving social and gender equity. If technology is to serve this purpose, access to it must be based on the principle of social inclusion. The *antyodaya* or 'unto the last' principle of Mahatma Gandhi is the pathway for inclusive economic growth.

The revolutions in agriculture, health and education witnessed during the last century were mostly the products of public good research supported by governments and philanthropic institutions. The contemporary world is, however, witnessing a shift from public good research to commercially profitable research supported by the private sector and protected by intellectual property rights (IPR). Even drugs which are important for the control of HIV/AIDS are available only at a cost which the poor cannot afford. This is why there was an agreement in the Doha Round of the WTO negotiations that in the case of drugs of importance for controlling diseases like HIV/AIDS, there must be a provision for the compulsory licensing of rights. It is now widely accepted that gross social and gender inequity will be threats to peace and human security. It is hence appropriate that Mr. Kofi Annan, the then Secretary General of the United Nations, made the following observations in a guest editorial in *Science* (Vol.299, 7 March 2003):

"The unbalanced distribution of scientific activity generates serious problems not only for the scientific community in the developing countries, but for development itself. It accelerates the disparity between advanced and developing countries, creating social and economic difficulties at both national and international levels. The idea of two worlds of science is anathema to the scientific spirit. It will require the commitment of scientists and scientific institutions throughout the world to change that portrait to bring the benefits of science to all".

UNDP has been rendering valuable service through the publication of an annual Human Development Report (HDR), the brainchild of the late Dr. Mahbul Huq. Nations which undervalue human resources and overvalue material resources tend to remain poor. HDR has helped to arouse political, public, professional and media awareness on the factors which enable nations to leapfrog in terms of human development, as for example China among developing countries, and the State of Kerala within our country. Unless political will expressed in speeches is converted into political action for achieving the goals of food, health, literacy and a clean environment for all, Kofi Annan's warning that the force of violence and war will destroy prospects for sustained economic development will come true.

The UNDP HDR for the year 2001 introduced an index for measuring technology achievement. India ranks very low in this index, in spite of its substantial advances in science and technology. The indicators used by UNDP for measuring technology achievement are largely those covered by intellectual property rights and private sector leadership.

Unfortunately, the Technology Achievement Index (TAI) of UNDP fails to take into account the contributions of public good research in improving human well-being in basic areas like food, water, health and energy security. I therefore felt that we should develop TAIs based on the impact of public good research supported by public funds. Dr. R. Chidambaram, Principal Scientific Adviser to the Government of India, gave his full support to this concept and the study was entrusted to MSSRF with financial support from the Office of the Principal Scientific Adviser. The present publication contains the findings of the study carried out by a dedicated team of scientists led by Dr. R. Rukmani and comprising Drs. Indumathi M. Nambi, S. John Joseph, N. Meganathan, M. Nirmala Devi, M. Prabu, K. N. Selvakumar, C. Surendran, and K. Susheela, Ms. N. Thenmathi and Messrs Karuna Krishnaswamy and V. Senthilkumar. The findings have been peer reviewed at regional Reality Check Workshops. The Project Review Monitoring Committee (PRMC) set up by the Principal Scientific Adviser, consisting of Professor V. L. Chopra (Chairman) and Drs. Panjab Singh, C. R. Bhatia and R. P. Gupta provided invaluable guidance.

The significance of public good research will be clear from the following data:

- Foodgrain production increased from about 45 million tonnes in 1951–52 to over 200 million tonnes at the beginning of this century.
- Productivity of major cereals increased from 700 kg per hectare in 1961–62 to over 1700 kg per hectare by 2001–02.
- The net area under irrigation increased from about 21 million hectares in 1951–52 to about 60 million hectares by the late 1990s; gross irrigated area has also increased by over 300 %. Groundwater irrigation has played the lead role in bringing more area under irrigation, thanks to technological advances.
- Annual milk production has gone up from about 20 million tonnes in 1950–51 to nearly 100 million tonnes in 2007, thereby taking India to the first position in the world in milk production.
- Both marine and inland fisheries have registered impressive progress: a major contribution to this progress has been made by scientific advances in the production of seed, feed, and induced breeding as well as crafts and gear.
- Science and technology coupled with social engineering have helped to promote conservation, restoration and commercial forestry and the regeneration of coastal mangrove wetlands.

- Significant progress has been made in the development of affordable drugs for the control of malaria, tuberculosis, leprosy, cholera and other diseases; small pox has been eradicated and leprosy is likely to be eradicated soon.
- Many nutritional disorders like those arising from micronutrient deficiencies have now affordable remedies through a food-cum-fortification approach.
- Rural drinking water supply has been made nearly universal through the design of simple water pumps and the application of remote sensing and hard rock drilling techniques.
- Rural energy systems have gained enormously from scientific work related to the harnessing of biogas, biomass, solar and wind and other forms of renewable energy.

Thus, the list of meaningful achievements brought about by public good research is large and impressive. The impact of such research is not generally captured when indicators based upon technologies covered by IPR are used. The task of developing technology achievement indicators based on public good research is not easy, because of the fact that for technology to strike roots and bear fruit, appropriate technology delivery systems and public policies and investment are needed. Also, the benefits cannot be measured only in metric or monetary terms. Non-monetary benefits like a general improvement in the quality of human life are equally important.

I hope the present publication will help to stimulate the birth of a new science — science for inclusive human development. It is appropriate that the Eleventh Five Year Plan aims to promote faster and more inclusive economic growth. It is important that the impressive progress recorded in this publication in such vital areas like agriculture, animal husbandry, fisheries, forestry, irrigation, energy, healthcare and drinking water is tapped for alleviating agrarian distress in over 30 districts of India where farmers' suicides are unfortunately prevalent. Can the technologies on the shelf now assist in improving the productivity, profitability, stability and sustainability of the farming systems prevalent in the agrarian hotspot districts? Can they help farm families with small holdings in unirrigated areas to improve their income from every drop of water and through crop-livestock-fish integrated farming systems? We cannot be silent on-lookers to the continued co-existence of mountains of affordable technology and acute agrarian distress. If the results contained in this publication are taken to the field, we can make the era of farmers' suicides history. Based on the present study, an inter-disciplinary and integrated effort in the farmer suicide hotspot areas should be a logical follow-up.

M. S. Swaminathan
Chairman,
M. S. Swaminathan Research Foundation

EXECUTIVE SUMMARY

The M. S. Swaminathan Research Foundation undertook a study on the *Measures of Impact of Science and Technology in India: Agriculture and Rural Development* with the principal objective of analysing significant technologies that have been developed in the public research system pertaining to the major sectors of the rural economy of India over the post-Independence period. Crop husbandry, animal husbandry, fisheries, forestry, irrigation, health, drinking water and energy have been the areas of concern.

Each one of the sectors considered has benefited from a large number of technological interventions. However, emphasis here has been on a few significant technological interventions that have helped in bringing about rapid transformation in a sector rather than analysing *all* the technological interventions. Such significant technologies, referred to as catalytic technologies, have been identified and various dimensions of technological achievement — development of the catalytic technology, diffusion of the catalytic technology, and the outcome or impact triggered by the catalytic technology — have been described. In crop husbandry, animal husbandry and fisheries the attempt has been to analyse technologies that have brought about significant changes in output, whereas the analysis on health, drinking water and energy pertains to technologies or interventions that have brought down the incidence of various diseases, improved access to drinking water and electricity, respectively.

Crop Husbandry

Adoption of modern technology in crop cultivation is a very important feature of agricultural development in Independent India. The varietal improvement programme, focusing on development of superior crop varieties through plant breeding, has been a vital component of modern agricultural technology. A detailed analysis of technological interventions has been undertaken with regard to some selected crops: rice and wheat among major cereals, maize and sorghum among nutritious millets, soybean and sunflower among oil seeds, potato among vegetables, sugarcane and cotton among non-food crops.

The ICAR system, with its elaborate network of research activities, has developed and released more than 3300 high yielding varieties and hybrids pertaining to various crops. Plant breeding techniques have been used to develop varieties and hybrids of crops with desirable characteristics such as high yield and improved quality as well as resistance to biotic (pests and diseases) and abiotic (salinity, drought etc.) stresses. Quality parameters taken into account during the varietal improvement programme vary across crops. For instance, the programme aims at improving the grain size, colour, milling and baking qualities in wheat, the cooking quality in rice, and the protein content in pulses. Breeding for different maturing varieties and the development of photoinsensitivity (which permits the cultivation of crops in non-traditional areas) are also areas of interest.

The development of varieties necessitated the development of the agricultural input sector too. Several changes have been triggered in cultivation practices, including use of fertilisers, land preparation, crop protection, use of agricultural machinery, processing, etc. Significant improvement in labour productivity has also occurred.

Area under cultivation as well as area irrigated has increased. A significant achievement in adopting high yielding varieties has been the quantum jump in yield of crops, leading to a corresponding increase in agricultural output in the country.

E1/Table 2.2: Area under Cultivation and Irrigation in India, 1951-52 to 1999-00

(million hectares)

Triennium centred around the year	Net Sown Area	Gross Cropped Area	Net Irrigated Area	Gross Irrigated Area
1951-52	120.53	134.26	21.01	23.01
1961-62	134.98	155.25	25.07	28.63
1971-72	139.04	164.38	31.49	38.56
1981-82	140.72	174.04	39.97	51.01
1991-92	142.45	184.56	49.32	64.97
1999-2000	141.59	190.43	55.98	76.92

Source: www.indiastat.com

E2/Table 2.6: Production of Foodgrains and Major Non-Food Crops, India

(million tonnes)

Triennium centred around the year	Total Cereals	Total Pulses	Total Food grains	Total Oilseeds	Sugarcane	Cotton Lint*
1951-52	45.33	8.67	54.00	4.97	56.56	3.22
1961-62	69.63	12.00	81.63	7.22	101.96	5.33
1971-72	92.60	10.94	103.54	8.62	121.60	5.82
1981-82	119.47	11.33	130.80	10.48	176.71	7.47
1991-92	161.72	13.03	174.75	19.11	241.03	10.32
2001-02	182.96	11.86	194.81	17.98	291.58	9.41

Note: * Refers to production in million bales of 170 kg each

Source: www.indiastat.com

E3/Table 2.7: Yield of Foodgrains and Major Non-Food Crops, India, 1951-52 to 2001-02

(kg per hectare)

Triennium centred around the year	Total Foodgrains	Total Oilseeds	Sugarcane	Cotton Lint
1951-52	546	445	31,539	87
1961-62	699 (2.50)	494 (1.05)	42,961 (3.13)	117 (2.94)
1971-72	848 (1.95)	519 (0.49)	48,902 (1.30)	128 (0.93)
1981-82	1,030 (1.97)	578 (1.08)	57,497 (1.63)	160 (2.28)
1991-92	1,406 (3.16)	762 (2.81)	65,142 (1.26)	232 (3.79)
2001-02	1,641 (1.55)	811 (0.62)	66,825 (0.26)	190 (-2.02)

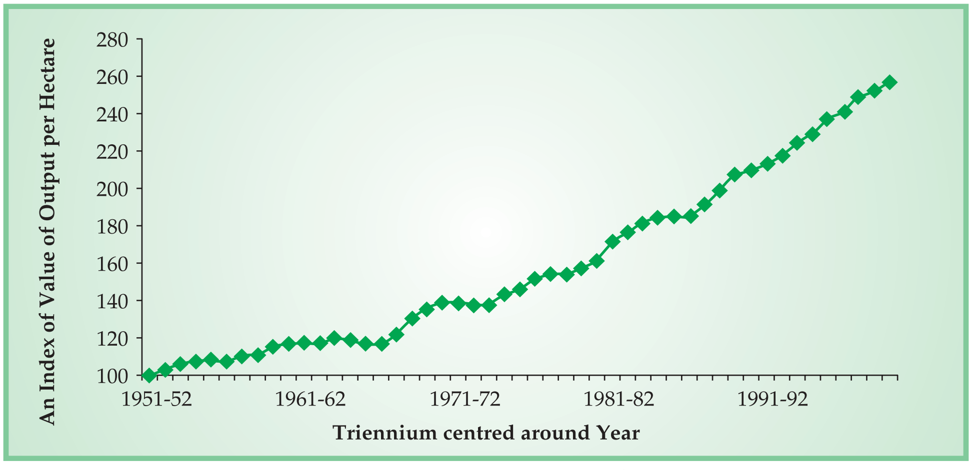
Note: Figures in brackets give the annual rate of growth of yield corresponding to the decade preceding the year of reference.

Source: www.indiastat.com

As far as rice is concerned, major achievements have been in developing varieties with shorter maturation, with resistance to pests and diseases and improvement in grain quality. In wheat, the significant impact of plant breeding efforts has been evidenced by a steady increase of yield levels as well as in release of late sown varieties. Improving the protein content in maize, the sucrose content in sugarcane, and the oil content in soybean have been important achievements. In sorghum, apart from concentrating on grain sorghum, the programme has concentrated on developing varieties exclusively for green fodder. The contribution of the varietal improvement programme in the case of sunflower has been with regard to development of cultivars with short duration and possibility of cultivation across the year. Varieties suitable for processing, as in the case of potato, have also been an important focus. Extensive work has been done on pest and disease resistance in cotton hybrids.

Appropriate indicators such as yield, production and value of output have been chosen to measure the impact or achievements triggered by the varietal improvement programmes in the sphere of crop husbandry. Further, an index of technology achievement has been computed using the value of output per hectare as the indicator for the period 1950–51 to 2000–01.

E4/Figure 2.1: Technology Achievement Index — Crop Husbandry



Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

The technology achievement index for the crop husbandry sector as a whole has more than doubled over the five decades; the index has increased for the individual crops too, with the extent varying across crops. However, while most of the crops registered rapid improvement in yield levels in the 1980s, the rate of growth of yield declined in the next decade. It is evident that there has been no breakthrough in technology in the 1990s even to sustain the growth levels achieved during the earlier decade. It is therefore very important that the government considerably enhances its efforts in agricultural research.

Irrigation

Expansion of irrigation in the country is in part related to a conscious policy decision of the government to invest in irrigation works and in part to development of technologies, such as drilling technology, leading to investment by individual farmers. Over the five decades and more since Independence, net irrigated area has more than doubled and this expansion underlies the significant improvement in agricultural productivity and production in the country.

Several technologies, major and minor, have played a crucial role in the development of irrigation in the country with regard to harnessing, distributing and managing water resources as well as in conserving and quantifying available water. The design and construction of dams in India have undergone several modifications based on new scientific inputs and experience over the years. Technology has enabled construction of large dams even in areas susceptible to seismic activity, which is a major breakthrough, particularly with regard to the flood prone north-eastern States. As regards sub-surface irrigation, high speed drilling technology has replaced traditional shallow dug wells by modern deep borewells in hard rock areas. The spread of tubewell technology has brought large tracts of the plains, particularly the Indo-Gangetic plains, under irrigation. Pumping technology has undergone major strides from low cost zero energy pedal pumps in shallow aquifers to high power pumps to reach deep aquifers in the hard rock areas. The use of several computer simulation models, remote sensing and GIS tools along with advanced imaging techniques have replaced the traditional methods of water resource quantification and management. In the areas of water conservation, the list of technologies is quite long, ranging from improvements in water conveyance to water application and on-farm conservation methods. Lining of canals using several scientific methods has resulted in significant reduction in water loss in many canal systems in the country. Rainwater harvesting, groundwater recharge and micro-irrigation technology have tremendous potential for water conservation in addition to other benefits.

E5/Table 3.2: Net Area Irrigated through Different Sources of Irrigation, India

(in '000 ha)

Triennium centred around the year	Canals	Tanks	Tubewells	Groundwater*	Other sources	Net Irrigated Area	Gross Irrigated Area
1951-52	8,613 (41.00)	3468 (16.51)	-	6,339 (30.17)	2,588 (12.32)	21,008 (100.00)	23,016 (100)
1961-62	10,568 (42.15)	4,651 (18.55)	431 (1.72)	7,430 (29.64)	2,420 (9.65)	25,070 (100.00)	28,631 (124)
1971-72	12,983 (41.22)	3,822 (12.13)	4,866 (15.45)	12,377 (39.30)	2,313 (7.34)	31,494 (100.00)	38,560 (168)
1981-82	15,808 (39.55)	3,165 (7.92)	10,212 (25.55)	18,593 (46.52)	2,406 (6.02)	39,971 (100.00)	51,006 (228)
1991-92	17,567 (35.57)	2,930 (5.93)	15,080 (30.53)	25,705 (52.04)	3,193 (6.46)	49,394 (100.00)	65,215 (283)
2000-01	16,049 (28.75)	2,476 (4.44)	22,318 (39.98)	34,397 (61.62)	2,901 (5.20)	55,823 (100.00)	76,240 (331)

Note: 1. * Groundwater refers to tubewells and other wells.
2. From the year 1993-94 onwards, data provided is provisional.
3. Figures in brackets in the last column refer to indices w.r. to 1951-52.
4. Figures in brackets in all other columns refer to percentage contribution of different sources of irrigation to NIA.

Source: www.agricoop.nic.in / statistics / sump2.htm

While government policies have focused on spreading canal, tubewell and borewell technology, they have sidelined traditional irrigation systems such as tanks and dug wells which have been performing equally well in terms of extent of areas irrigated in the 1950s. Particularly, tank irrigation has declined from 16 % to about 4 % of net irrigated area over the five decades since 1951–52. Tanks are vital sources of irrigation in the hard rock areas with uneven distribution of rainfall and poor recharge characteristics. Groundwater in these areas has reached dangerously low levels and is unsustainable in the long run.

Revival of these traditional irrigation structures and use of technology to enhance their performance are important strategies to be considered in the future.

Animal Husbandry

Besides complementing and supplementing agriculture, animal husbandry provides security to farmers, especially when agriculture fails. Livestock are essential to millions of poor households across the country not only as a source of income but also as a major source of protein, supplementary nutrition, draught power, fertiliser, fuel and a store of wealth. In the post-Independence period, the Indian livestock sector has undergone a major shift, mainly due to the introduction of new technologies.

Various technological interventions in the post-Independence period in the livestock sector of the country have made significant improvements in the production, productivity and per capita availability of livestock products. To improve milk production in the country, which was perceptibly low in 1960, multi-pronged approaches in breeding, health cover, feeding and marketing were initiated by the government through various development programmes. Cross-breeding and upgradation were done to improve the productivity of indigenous cows and local buffaloes, respectively. Artificial insemination with improved germplasm by using frozen semen has been the most strategic intervention in increasing milk production. Vaccines against various diseases were developed and cattle in every part of the country were vaccinated, which resulted in reduced animal losses as indicated by the disease incidence particulars. Various feeding technologies were developed to exploit the full potential of cattle along with the creation of marketing facilities for rural milk. These combined measures resulted in improvement in milk production to 91 million tonnes in 2004, with India standing first in the world in milk production. The growth in the dairy sector was significant, as indicated by the two-fold increase in the value of output per milch animal.

E6/Figure 4.2: Milk Production

Source: Basic Animal Husbandry Statistics (various years)

Introduction of high-yielding varieties of eggers — Rhode Island Red, White LegHorn, Babcock, etc. — during the 1970s and broilers — Cobb, Ross, etc. — in the 1980s has been a benchmark in the development of the poultry sector in India. Along with this, the development of newer vaccines and diagnostic kits, least cost formulation of feeds, and adoption of newer management techniques in rearing have contributed to improving productivity and production. The average productivity of birds in terms of weight of eggs increased more than twice between 1961 and 2001.

Fisheries

Fisheries deal with farming of aquatic organisms (aquaculture) as well as their collection from open water (capture fisheries). Aquaculture as well as capture fisheries can be undertaken in freshwater as well as marine environments. Over the years, the fish production system has been subjected to several technological interventions pertaining to production, processing, product formulation, packaging and storage. Intensification of fish culture with biotechnological tools, diagnosis and control of diseases that affect fish, improvement in fish nutrition from feed formulation to encapsulation, and assessment of water quality are some of the technological interventions pertaining to aquaculture that have been developed over the years in India. As far as capture fisheries are concerned, major technological intervention has been with regard to development of different kinds of fishing craft and gear.

Being basically a small-scale enterprise, freshwater aquaculture provides for the domestic food security of rural India. The Central Institute of Freshwater Aquaculture (CIFA) has virtually revolutionised freshwater aquaculture in the country by standardising three technologies: (i) induced breeding of carp through administration of pituitary gland extract; (ii) carp nursery rearing and pond management practices; and (iii) composite carp culture, where the different layers of the pond ecosystem are effectively utilised. Carp production has contributed a major share to inland fish production, increasing from 34 % in 1986 to 65 % in 2000. To promote carp production with adequate seed availability, hatchery production of seeds by induced breeding was also developed.

One of the most important and effective national programmes for the promotion of rural aquaculture development has been the Fish Farmers Development Agencies (FFDAs), started in 1973–74. FFDAs provided a package of technical, financial and extension support services to fish farmers. They arranged suitable water areas on long-term lease, identified beneficiaries, and provided incentives in the form of subsidies / grants for the construction / rehabilitation of ponds and for input supplies.

During the five decades after Independence, the Indian marine fisheries sector has transformed from a traditional, subsistence avocation into a market-driven multicrore industrial sector. Marine fish production has increased through successive stages, first with a change from natural to synthetic fibres in gear fabrication, introduction of mechanised craft, introduction of trawl nets and, mainly, motorisation of fishing craft. The Bay of Bengal Programme (BOBP), financed by the Swedish International Development Agency from 1977 to 1989, has brought about significant changes in the life of the artisanal fishermen through several strategic interventions, including the initiation of post-harvest technologies like hygienic curing and smoking of fish, introduction of insulated fish boxes for transportation from landing centres to markets, and the enhanced role of fisherwomen in coastal fishery development.

These developments have paved the way for what is hailed as the ***Blue Revolution*** or ***Aquaplosion*** in India. The Blue Revolution has resulted in an increase in per capita availability of fish in the country, from 3.82 kg / annum in 1986 to 5.55 kg / annum in 2000.

Forestry

Improvement in the area under forests in India is largely due to interventions in the aspects of conservation and management of the fast dwindling natural forest, protection of endangered flora and fauna, wildlife management and development of high yielding plantations. The impact of science and technology on the forestry sector has been evidenced on constituents such as conservation forestry, restoration forestry, production forestry, wildlife management, protection forestry, and research and utilisation forestry. However, the peculiarity and complexity of forestry (as compared to the other sectors discussed in this report) makes it difficult to understand and evaluate the impact of technology in forestry.

Independent India has been committed to conserving her forest resources, and suitable policies have been evolved and adopted with regard to the protection of forests. The Forest Research Institute (FRI) in Dehra Dun extends its functions over all of India, with branches dealing with silviculture, forest management, forest zoology, forest botany, forest chemistry and forest economy. The focus has been on the recognition of the role of forests in ecological balance, environmental stability, biodiversity conservation, food security and sustainable development.

The impact of satellite technology in forest management has resulted in the appreciation of the status of forest, its deforestation and its condition. The Forest Survey of India's biennial assessment of forest cover has helped in understanding the complexity and challenges facing the country. This challenge has been responsible for the development of an Indian instrument of forest management, namely, the criteria and indicators set out by the Bhopal-India process.

In conservation forestry, data and information generated by the Rapid Biodiversity Assessment has helped in formulating strategies both for *in situ* and *ex situ* conservation. In restoration forestry, significant work in rehabilitation of mangroves is being done all along the Coromandel Coast due to the technology developed and diffused by the M.S. Swaminathan Research Foundation.

In restoration of forests to original status, Joint Forest Management technology is playing a perceptible role all over the country by enlisting the active participation of people motivated by village forest committees. In production forestry, the large-scale plantation programme as well as clonal forestry and agro forestry have an outstanding record of application diffusion and achievement both in the public and private sectors. In wildlife management, the Wildlife Institute of India has developed relevant grassroot level technology in wildlife management, significant among them being methods to conduct census, radio collaring, use of GPS in conjunction with GIS, and conservation genetics of tigers and turtles. In forest protection, the establishment of the Wildlife Forensic Cell and its role in identification by use of DNA technology, thereby securing conviction for forest offences, has been a major breakthrough.

Consequent to various measures taken by the state, the area under forests has registered an increase over the decades since 1950–51.

E7/Table 6.1: Area under Forests in India

Land use	1950-51	1960-61	1970-71	1980-81	1990-91	1999-2000
Area under forests (in million ha)	40.48 (14.2)	54.05 (18.1)	63.91 (21.0)	67.47 (22.2)	67.80 (22.2)	69.02 (22.6)

Note: Figure in brackets give the percentage of geographical area under forests.
Source: Agriculture Statistics at a Glance (2003)

Health

Since Independence, several national level health programmes have been initiated in our country, to tackle specific diseases. The objectives of these health programmes have been

- to control, that is, to bring down the prevalence or incidence rate of specific diseases to a level where they no longer remain a public health problem
- to eradicate the health problem

E8/Table 7.16: Technological and Managerial Interventions in the Health Sector

Disease	Catalytic technology	Strategic interventions
Communicable diseases		
Malaria	Diagnosis of malaria by microscopic examination of the blood smears of patients after staining with JSB staining method. Presumptive & radical treatment with chloroquine & primaquine; insecticidal spray with DDT	National Malaria Control Programme, 1953 National Malaria Eradication Programme, 1958 Modified plan of operation under NMEP, 1977
Leprosy	Multi-drug therapy by Rifampicin, Clofazimine & DDS	National Leprosy Control Programme, 1955 National Leprosy Eradication Programme, 1983 Modified Leprosy Elimination Campaign, 1997
Tuberculosis	Development of DOTS strategy with multi-drug therapy, Rifampicin the major bacterial drug being one among them; microscopic examination of sputum smear; BCG vaccination.	National Tuberculosis Control Programme, 1962 A Pilot Project of the Revised National Tuberculosis Control Programme, 1993 Revised National Tuberculosis Control Programme Phase I, 1997
Cholera & Diarrhoeal Disease	Oral Rehydration solution and intravenous fluid treatment	National Cholera Control Programme, Fifth Five Year Plan National Diarrhoeal Disease Control Programme, 1978 National Oral Rehydration Therapy, 1986-87
Non-Communicable diseases		
Blindness	Cataract surgery	National Trachoma Control Programme, 1963 National Programme for the Control of Blindness, 1976 Blindness Control Project, 1994-95
Vaccine-preventable diseases		
Small pox	Small Pox vaccine	National Small Pox Eradication Programme, 1962 Surveillance followed by quick containment, 1973
Diphtheria Pertussis Tetanus Poliomyelitis Measles Tuberculosis	Combined Diphtheria, Pertussis, Tetanus vaccine Oral Polio vaccine Measles vaccine BCG vaccine	Expanded Programme of Immunisation, 1978 Universal Immunisation Programme, 1985 Child Survival and Safe Motherhood Programme, 1992 Reproductive and Child Health Programme (RCH), 1997 Pulse Polio Immunisation Programme, 1995
Major Nutritional Deficiency Disorders		
Vitamin A deficiency Protein energy malnutrition	Vitamin A supplementation Low cost energy-rich food	National Vitamin A prophylaxis programme, 1970 integrated with Child Survival and Safe Mother hood Programme, 1992 Special Nutrition Programme, 1970 Balwadi Nutrition Programme, 1970 Integrated Child Development Service, 1975 Mid-day Meal Programme, 1961
Iron and Folic acid deficiency anaemia	Iron and Folic Acid tablets	National Nutritional Anaemia Prophylaxis Programme, Fourth Five Year Plan
Iodine deficiency disorders	Iodisation of salt	National Goitre Control Programme, 1962 Universal Iodisation of Salt, 1983 National Iodine Deficiency Disorders Control Programme, 1992

The impact of the health programmes is measured using parameters like prevalence, incidence, morbidity, mortality rates, etc. of diseases. However, data on incidence or prevalence of various diseases are not available separately for rural areas and pertain to the country as a whole. Therefore, while it has not been possible to estimate the impact of specific programmes on rural health, given that 70 % of India's population live in rural areas, the estimates for the country may be taken to reflect the rural reality.

E9/Table 7.17: Impact of Various Health Programmes on Specific Diseases

Classification of Diseases	Disease	Indicator	Reference Period	
Communicable Diseases	Malaria	Incidence	75 million in 1947	1.64 million in 2003
	Leprosy	Incidence Rate per 10,000 population	5.9 in 1991	2.3 in 2004
	Tuberculosis	Mortality due to disease	100 per 1 lakh population in 1964	37 per 1 lakh population in 2002
	Cholera	Mortality of reported cases	37 % in 1960	0.07 % in 2003
Vaccine Preventable Diseases	Small Pox	Incidence	84,902 in 1967	Nil in 1976
	Poliomyelitis	Incidence	28,257 in 1987	268 in 2001
	Diphtheria	Incidence	12,952 in 1987	4954 in 2001
	Pertussis	Incidence	1,63,786 in 1987	28,900 in 2001
	Neonatal Tetanus	Incidence	11,849 in 1987	1354 in 2001
	Measles	Incidence	2,47,519 in 1987	45,301 in 2001

Infant mortality rate (IMR) is considered a sensitive indicator of the socio-economic conditions of a population. IMR is influenced by medical as well as non-medical factors. The level and quality of medical care available for deliveries as well as for ante-natal care, the reach of the immunisation programme, the nature of nutritional interventions made available for pregnant women, availability of safe drinking water and sanitation, all these factors particularly influence IMR. The universal immunisation programme is perhaps the most important medical intervention in bringing about a decline in IMR in rural India, which has shown a sharp fall from 138 per 1000 live births in 1971 to 69 in 2002. Life expectancy at birth is influenced to a very large extent by decline in mortality rate in general and infant mortality rate in particular, decline in incidence of diseases and improvement in sanitary conditions. Therefore, the improvement in life expectancy of an average villager in India may be taken as a summary measure of achievements in the overall health status of the population. Life expectancy at birth of the average rural Indian in 1970-75 was 48 years and it rose to 61.2 years by 1998-2002.

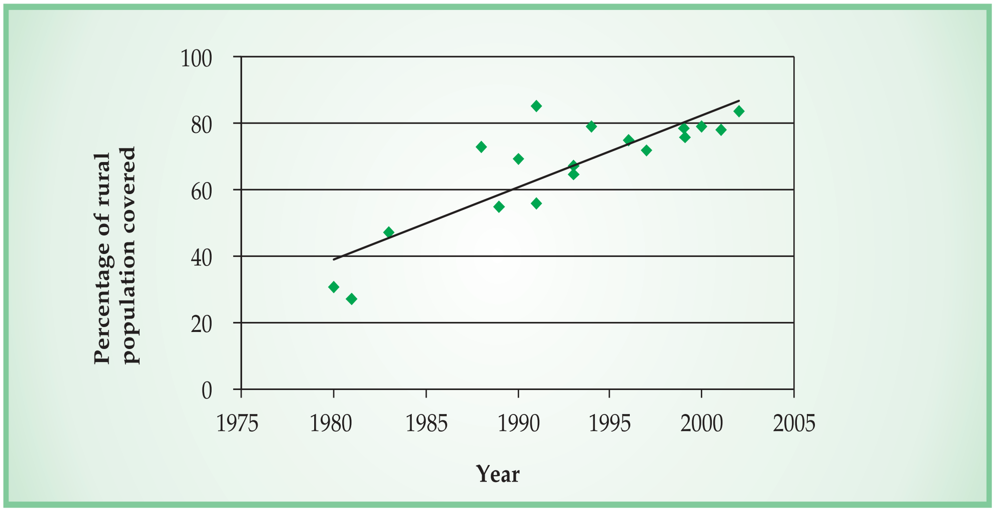
While the improvement in health in the post-Independence period in India cannot be denied, it is important to note that the achievements are far from adequate.

Drinking Water

Provision of safe drinking water that is free from biological contamination (guinea-worm, cholera, typhoid, etc.) and chemical contamination (excess fluoride, brackishness, iron, arsenic, nitrate, etc.) to all rural habitations continues to remain a challenge in India. In 1986, the National Drinking Water Mission, which was later renamed as the Rajiv Gandhi National Drinking Water Mission (RGNDWM), was launched. This accelerated the pace of several programmes by providing a renewed form of mission approach for implementation. There has been rapid growth in coverage of rural drinking water supply from 56.3 % of households in 1985 to 98 % of households by 1999. The introduction of borewell drilling technology and the advent of new and more durable hand-pumps improved the coverage in previously inaccessible areas.

While the percentage of rural population provided with infrastructure for drinking water has grown from 18 % in 1974 to close to a 100 % in 2005, the actual usage of this infrastructure for access to drinking water is much less at 84 %. This lacuna is due to several reasons including groundwater depletion and water quality constraints. The government is currently focusing its investments into filling this gap. A significant amount of pump breakdown problems have been taken care of with the introduction of Mark III pumps and a strong back-up by village level operation and maintenance schemes for hand-pumps. In many States such as Tamil Nadu, a step further has been taken by replacing all the hand-pump schemes,

E10/Figure 8.2: Growth in Rural Drinking Water Supply



Source: WHO / UNICEF (2001, updated on the web in 2004)

wherever feasible, with piped water supply which is more reliable and sustainable in terms of operation. Measures such as rainwater harvesting and groundwater recharge are being introduced as an integral part of all rural water supply schemes. These operations have to be geared up with the aid of the latest technologies so that the results can be expedited. Irrespective of the difference between drinking water coverage and usage, the growth that has taken place in this sector is quite remarkable.

Energy

Power generation has risen impressively in post-Independent India. This has been a consequence of planned investment, successful technology absorption from abroad, indigenous capacity building, and modification of technology to suit local conditions. This growth in power generation has been led by growth in coal-based thermal power, including additional power stations, higher installed capacity of thermal power plants and higher power generation through gains in efficiency. Improvements and technological innovations in hydroelectric turbines, generators and governing equipment have produced a new generation of hydro equipment that offers higher efficiency, lower cost and improved reliability. Nuclear power plants require an advanced level of technology and research and hold a place of pride on the Indian technology shelf. Nuclear energy is expected to increase steadily in terms of share of total power. Most of India's achievement in this sector is the result of indigenous technology development covering the complete nuclear cycle — from uranium exploration and mining through fuel fabrication, to heavy water production, reactor design and construction, to power generation and waste management.

E11/Table 9.3: Progress in Power Generation in India

(billion kwh)

Year	Utilities				Non-utilities	Total	Power generated per capita (kwh)
	Thermal	Hydro	Nuclear	Total			
1950-51	2.6	2.5	--	5.1	1.5	6.6	18.28
1960-61	9.1	7.8	--	16.9	3.2	20.1	46.31
1970-71	28.2	25.2	2.4	55.8	5.4	61.2	113.12
1980-81	61.3	56.5	3.0	120.8	8.4	129.2	190.28
1990-91	186.5	71.7	6.1	264.3	25.1	289.4	344.93
2000-01	408.1	74.5	16.9	499.5	55.0	554.5	544.16

Note: Thermal includes wind.

Source: Economic Survey (2004-05)

Power reach to rural areas has been made possible by the rural electrification policies, through subsidies and by successfully extending the power grid to remote areas. Rural India lags behind urban areas in the consumption of power. Village electrification has made rapid strides in terms of numbers, but village electrification simply represents the presence of transmission lines that run into a village and hence the potential for electrification in the village for potential consumers. Household electrification has improved steadily over the years. Directed programmes to provide electricity to poor and under-privileged communities have reduced inequality in access to power. Agricultural electrification has been a success story considering the difficult terrain and fragmented farmlands and has been a significant factor in increasing productivity. Rural enterprise electrification is still quite low and has not kept pace with the other sectors. Decentralised renewable energy has been seen to be the direction to go in rural areas that are harder to reach through transmission and distribution lines from a central plant, as well as for sustainability and environmental friendliness. India is one of the world leaders in renewable energy programmes.

India has one of the largest and most complex power grid systems among developing countries, and has indigenously acquired competence in demand forecasting, power plant design and creation, technical specifications, project management and engineering capabilities. However, despite tremendous advances in energy production, demand for power still outstrips the supply.

Summing Up

While the MSSRF study has attempted an explication of the perspective that significant technological achievements have been realised by the major sectors of the Indian rural economy, it has not done justice to every dimension of the enquiry. First, the study has analysed the impact of technological interventions in very broad terms and there has been no attempt to isolate the pure effect of technology. Second, it has not examined the reasons for the variance between potential and actual productivity or that between international levels of productivity and corresponding Indian levels. Third, while the study has analysed the role of public-funded research in the development of various catalytic technologies, there has been no substantive investigation of various other policies that were put in place to successfully operationalise the catalytic technologies. Fourth, technological achievement has been analysed in isolation from the social and environmental impact of technology.

The progress in production with regard to crops, milk, eggs and fish, improvement in health status, and growth in access to electric power and drinking water for India's rural population over the post-Independence period is the result of the proactive role played by the state in promoting R&D that has contributed the technologies crucial for a breakthrough in production and promotion of people's access to basic facilities. However, the analysis clearly shows a tapering of growth in the 1990s compared to the 1980s in the major sectors of the rural economy. The rate of growth of yield of almost all major crops as well as the growth rate of production of milk, eggs and fish has declined in the 1990s. This has very serious implications for the food security of the people and indicates the urgent necessity for an agricultural renewal in the country.

1

INTRODUCTION

1.1 An Overview

This study undertaken by the M.S. Swaminathan Research Foundation (MSSRF) is a preliminary attempt to capture the impact of significant technological interventions on the rural economy of India over the post-Independence period. Conceived primarily in the context of assessments made by the United Nations Development Programme's (UNDP's) Human Development Report of 2001 concerning the technological achievement of various countries including India, it covers all the components of agriculture — crop husbandry, animal husbandry, forestry, inland and marine fisheries — as well as health, water, and energy. UNDP's Report set forth a methodology to calculate a Technology Achievement Index (TAI) on a global scale, intended to serve as an indicator of the progress made by different member states of the United Nations in the area of technology achievement. The indicators used for developing TAI were based on the following components:

1. Technology Creation
   - Patents granted to residents
   - Receipts of royalties and licence fees
2. Diffusion of Recent Innovations
   - Internet hosts
   - High and medium technology exports
3. Diffusion of Old Innovations
   - Telephones
   - Electricity consumption
4. Human Skills
   - Mean years of schooling
   - Gross tertiary science enrolment ratio

Using the above measures of technology achievement, India was ranked 63rd among the 72 countries considered.

Reacting to the estimation of India's position in the Technology Achievement Index (TAI), experts have argued that the indicators chosen to reflect technology were largely related to profit-driven research, while the dominant sector of research in India is in the public domain, carried out in institutions and universities supported through public funds. As a scientist associated with Indian science policy remarked, “A nation may be a great technological achiever without receiving royalties and license fees for export of technology. India’s ‘green revolution’ to reach self-sufficiency of food and its ‘white revolution’ to achieve the number one position as the highest milk producer in the world brought no royalties, but they have contributed to its human development, touching the lives of millions of Indians like no other factors have. India’s finding a place in the top league of nations as a country which is able to design, fabricate and launch its own satellites (not only launching its own satellites, but also that of Germany and Korea), its ability to make and sell supercomputers, etc., do not seem to count at all in the way the indicators have been designed.” (Mashelkar undated) Moreover, UNDP’s TAI does not reflect the technological advancement attained by different sectors in the economy. According to Swaminathan, “instead of the first three criteria on technology creation and diffusion, there should have been others oriented towards the majority of our population. These criteria could take into account innovations in agriculture, fisheries and other aspects concerned with the rural sector” (Swaminathan 2001).

In this context, the Office of the Principal Scientific Adviser to the Government of India has initiated a series of studies under the umbrella title *Measures of Progress of Science and Technology in India*, to examine the progress made in various sectors in India in the post-Independence period. The current study *Measures of Impact of Science and Technology in India: Agriculture and Rural Development* is part of this series.[1] The main objective of this study is to provide an analysis of technological interventions and their outcomes across various sectors pertaining to rural India. Thus, this is not an attempt to counter the assessment made by UNDP, but to analytically document the technological achievements in the major areas of India’s economy.

Researchers pursue different methodologies to assess a country’s scientific and technological capabilities, achievements and efficiencies. While some studies use broad indicators that supposedly capture technological advances, others assess the productivity performance of different sectors by estimating total factor productivity (TFP). TFP is a productivity index that is related to technical change and change in technical efficiency. A considerable amount of literature has evolved using these two basic approaches: The indicator/index approach that seeks to provide a broad picture of technological development and the TFP approach that measures the effect of technology on productivity.

Many of these studies attempt an inter-country comparison of scientific and technological achievements. While a comprehensive review of such work is beyond the scope of this report, a brief discussion on a few of these studies is attempted. The purpose of this discussion is twofold: first, to provide an understanding of the relative position assigned to India, compared to other countries, with regard to various measures of technological achievement; second, to understand the contribution of technology to growth in agriculture, the major sector in rural India.

In a recent publication in *Nature*, David King has evaluated 31 countries with regard to publications covering all fields of science and engineering (King 2004). The exercise measured the scientific capability of a country by the quantity and quality of research publications produced in it. The quantity is generally captured by the number of research papers published and the quality of publications by the number of

[1] The context in which this study is being sponsored is explained in Chidambaram (2005).

times the paper is cited by other authors — the citation index. According to King's analysis, over the period 1997 to 2001, 35 % of the world's scientific and engineering publication was from the United States. This was followed by the United Kingdom with 9.43 % and India's publication accounted for only 2.13 %. So, while the United States and United Kingdom are ranked first and second with regard to the number of publications, India is ranked 13th among the 31 countries considered. Further, the percentage share of world citations or the citations share index, for the period 1997 to 2001 is 49 % for the United States, 11 % for the United Kingdom and 0.86 % for India. This implies that the share of citations for India is lower than its share of publications while the picture is reversed for the countries at the top of the list. The citation rate per paper between 1993 and 2002 puts Switzerland at the head with 1.59, United States in the second position with 1.41, and India in last position with 0.40. The position of India based on the share of the top 1 % of highly cited publications between 1997 and 2001 is 22 among 31 countries. Clearly, as per this research finding, India ranks poorly with regard to the quantity of publications as well as the citations of these publications. However, the number of publications per se or the frequency of citations need not necessarily be an ideal summary measure to reflect a country's scientific capability or its capacity to create technological innovations. David King himself notes that the rankings of countries on the basis of publications can hide important developments within a country. Referring to China and India he says: "[These countries] have developed their science base rapidly and effectively over the past few years. India's major science institutes have significant strength, produce high quality graduates, and have made critical contributions to the country's sustained economic growth, as exemplified by the Bangalore software phenomenon"(ibid). Moreover, Mashelkar, using the same data provided by David King, estimates that the number of publications per gross domestic product per capita per year is highest for India, followed by China and the United States of America (Mashelkar 2005). Sikka and Gupta have shown that research expenditure on science and technology per capita or per scientist is abysmally low in India. In the year 2003, per capita research expenditure on science and technology is about US$ 5.5 in India, while it is double that level in China at US$ 11.7, US$ 460 in the United Kingdom and US$ 705 in the United States of America (Chidambaram 2005). This analysis implies that an increase in R&D expenditure as well as an increase in investment per scientist may bring about an improvement in the number of publications and citations in India.

The Shanghai Jiao Tong University has published a list of the top 500 world universities *(http://ed.sjtu.edu.cn/ranking.htm)*. The ranking is based on five parameters: Nobel laureates on the faculty of physics, chemistry, medicine and economics; highly cited researchers (1981–1999) in 21 broad categories; articles published in *Nature* and *Science* (2000–2002); articles in the Science Citation Index and Social Science Citation Index; and average academic performance of a faculty member. In 2003, only three Indian universities figured in the list of the top 500 universities in the world: the Indian Institute of Science, Bangalore, and the Indian Institutes of Technology at Kharagpur and Delhi. Even on the Asia Pacific list of universities, only these three institutes from India figure in the top 100. Of the top 20 universities, 15 are in the United States, 4 are in the United Kingdom and one in Japan. Thus, India's scientific capability in relation to other countries is estimated to be quite low by this ranking too.

With regard to studies that estimate the total factor productivity in the agricultural sector, there is enough empirical evidence available on the importance of productivity growth in this sector in the post-Independence period in India.[2] Total Factor Productivity, which is output per unit of input in value terms, is estimated as a residual, using index number techniques. Different methods are used in measuring the total factor productivity growth and there are several measurement problems associated with these estimates, such as errors in the measurement of inputs, errors in assigning weights to different inputs, omission of inputs, etc.[3] Moreover, the selection of an appropriate production function is also a controversial issue. However, our purpose here is not to discuss the problems in estimation or interpretation of TFP but to provide an overview of the literature on the productivity performance of India.

Martin and Mitra (2001) provide three alternative estimates of TFP growth in agriculture across some developing countries for the period 1967 to 1992. By all three estimates, the TFP growth in India is positive, indicating the affirmative effects of technological progress in promoting agricultural growth in the country. However, the TFP growth in India for agriculture is lower than the average TFP growth for agriculture in 23 developing countries. While the TFP growth ranges between 1.52 and 2.29 for India's agricultural sector, the corresponding rate for the overall average of 23 developing countries lies between 2.26 and 2.69.

Rao and Coelli (2004) have examined growth in agricultural productivity over the period 1980 to 1995 in 97 countries. The average annual rate of growth of TFP in agriculture for all 97 countries is estimated at 2.7 %. The corresponding rate for India has been very modest at 1.6 %. China has had the most striking TFP growth of 6.8 %. Even while India's productivity performance in agriculture, in relation to other countries, is estimated to be quite low, the analysis clearly brings out the positive impact of knowledge and technology on the growth performance of Indian agriculture.

Avila and Evenson have analysed TFP growth estimates for the crops and livestock sector over 1961 to 1980 and 1981 to 2001 for India, Bangladesh, Nepal and Sri Lanka (Kumar and Hossain 2004). India's performance has been better than that of Bangladesh, Nepal and Sri Lanka in both these time periods, with TFP growth estimated at 1.92 % per annum during 1961 to 1980 and 2.41 % per annum during 1981 to 2001. Coelli and Rao (2003) have also analysed TFP growth estimates for the crops and livestock sector in India for the period 1980 to 2000 and it has been a modest 0.9 % per annum.

This brief review on estimates of total factor productivity growth in agriculture in relation to other countries indicates a relatively modest but positive growth experienced by India. Analysing the productivity performance in Indian agriculture across different time periods, Dholakia and Sivasubramonian stress the significance of total factor productivity in agricultural growth in the post-Independence period in India (Dholakia 2001; Sivasubramonian 2004). According to Sivasubramonian, output per unit of input in the agriculture sector grew at the rate of 1.13 % over the period 1950–51 to 1999–2000. The contribution of TFP accounted for 43 % of GDP growth in agriculture — the most important source of growth — over the post-Independence period. That is, the advances of knowledge as well as other non-quantifiable influences such as government policies, scientific R&D, etc., have played a very significant role in promoting the growth of GDP in the agricultural sector in India. In the

[2] The entire review of total factor productivity studies is based on K L Krishna's succinct presentation on this aspect. See Krishna (2004).

[3] Krishna (2004).

1980s and 1990s, total factor productivity growth's contribution to output growth was above 55%. Dholakia focuses on two time periods, 1960–61 to 1985–86 and 1986–87 to 2000–01, and estimates that the contribution of total factor productivity to gross domestic product in agriculture was 17 % in the first period and 42 % in the second period. Thus both these recent studies provide detailed empirical evidence that point towards the importance of technology in the agricultural growth of India, particularly since the 1980s.

In sum, despite India's relatively low ranking using some indicators of technological achievement, there is enough evidence to show that as far as agriculture is concerned, technology has contributed significantly to the overall progress of this major sector.

1.2 The MSSRF Study

Given that the significant role played by public domain research in achieving progress across various sectors of the rural economy of India during the post-Independence period is often not taken into account while assessing the country's performance, the current study proposes to fill this gap. The principal objective has been to analyse significant technologies that have been developed in the public research system as well as to examine the impact triggered by these technologies. Crop husbandry, animal husbandry, fisheries, forestry, irrigation, health, drinking water and energy have been the areas of concern.

The definition of 'technology' that has been adopted in this study — *the steps taken in the application of scientific knowledge in achieving some goal* — has covered a broad field. Each one of the sectors considered has benefited from a large number of technological interventions. However, emphasis here has been on a few significant technological interventions that have helped in bringing about rapid transformation in a sector rather than analysing *all* the technological interventions. Such significant technologies, referred to as catalytic technologies, have been identified across the chosen sectors on the basis of discussion with experts and by reviewing the literature. In each sector, after the identification of the catalytic technology, various dimensions of technological achievement, namely, development of the catalytic technology, diffusion of the catalytic technology, and the outcome or impact *triggered* by the catalytic technology have been captured. In the sectors of crop husbandry, animal husbandry and fisheries the attempt has been to analyse technologies that have brought about significant changes in output, whereas the analysis on health, drinking water and energy pertains to technologies or interventions that have brought down the incidence of various diseases, improved access to drinking water and electricity, respectively. Given this methodology, there have been no attempts in this study to either isolate the 'pure' effect of technological interventions or make an assessment of technical efficiency.

In general, in India, technologies have had a catalytic impact on an entire sector only when they have received support from the State through suitable public policies. Thus, the technologies that have been identified as catalytic technologies across sectors are those that have been either developed by public research or adopted and promoted by State machinery. This implies that even while there have been a number of locally relevant technologies developed either through traditional knowledge systems or private or public research, they have not been covered in this study. Only dominant technologies that have brought about a whole spectrum of changes in a sector have been considered, though the details of policies that have contributed to the success of any of the technologies have not been analysed. This study relies on published secondary data covering a time span of four to five decades, say from 1951 to 2001, with the exact time period varying across sectors.

The MSSRF study report has been organised as follows:

- Chapter 2 is a discussion on the developments in the crop husbandry sector where the varietal improvement programme has been identified as the catalytic technology. The nature and extent of development of the varietal improvement programme with reference to nine crops — rice, wheat, maize, sorghum, sunflower, soybean, potato, cotton and sugarcane — and the impact triggered by this development has been analysed in detail. Some of the indicators used to discuss the impact of technological intervention in the crop husbandry sector are yield per hectare, production, per capita availability, and value of output per hectare. Using the value of output per hectare, an index of technology achievement for various crops as well as for the entire sector has been computed for the period 1951–52 to 1999–2000.

- Chapter 3 provides an overview of irrigation development since the 1950s and highlights the role of technology in irrigation development. Technological interventions that aimed at development and utilisation of water resources as well as those technologies that aimed at water management and conservation have been discussed. Using the gross irrigated area as an indicator, the irrigation diffusion index has been calculated for the five decades from 1950–51 to 2001–02.

- Chapter 4 discusses the developments in the dairy and poultry sector in post-Independent India. The nature of the technological interventions experienced by these sectors as well as the impact of these interventions on production and productivity of livestock products such as milk and eggs has been analysed. In the dairy sector, a multipronged intervention covering the spheres of breeding, health, feed and marketing has been responsible for increasing the production of milk, while the introduction of high-yielding varieties of poultry breeds and broilers has been identified as the catalytic technology in the poultry sector.

- Chapter 5 sets out the technological and institutional interventions with regard to fisheries and the impact of these interventions on fish production and productivity in the country as a whole. While carp culture has been recognised as the catalyst in inland fisheries, the most important technological intervention as far as marine fisheries is concerned has been improvement in craft and gear. Using the data on carp production over the years 1986 to 2000 and marine fish landings over 1950–51 to 2003–04, indices of technology achievement in the fisheries sector has been computed.

- Chapter 6 analyses the technological interventions with regard to various dimensions of forestry, namely, conservation, restoration, production, protection, research and utilisation forestry, and wildlife management. As it is difficult to assess the goods and services flowing to the nation because of forestry and given that the benefits of forestry are not solely related to technological interventions, there has been no computation of an index of technological achievement in this chapter.

- Chapter 7 discusses the technical as well as managerial aspects of the various health programmes initiated in post-Independent India with regard to some major diseases. While the impact of the health programmes has been measured using parameters like prevalence, incidence, morbidity, mortality rates, etc., of diseases, the life expectancy rate has been used as an indicator to assess the progress in the overall health status in rural India.

- Chapter 8 traces the role of technology in the rural water supply programme and discusses the progress in coverage of habitations with safe drinking water in rural India over time.
- Chapter 9 examines the major technological interventions in thermal, hydro and nuclear as well as renewable energy sources and provides an analysis of progress in supply and improvement in consumption of power in rural India. Growth of electrification in rural India has been analysed in terms of coverage of households, villages, pump-sets and enterprises from 1981 to 2001, and a power diffusion index has been calculated for that period.
- Chapter 10 provides the concluding observations.

References

Chidambaram, R. 2005. "Measures of Progress in Science and Technology" *Current Science,* Vol.88, No.6.

Coelli, T.J. and D.S.Prasada Rao. 2003. "Total Factor Productivity Growth in agriculture: A malamquist index of 93 countries, 1980–2000." Working Paper Series 02/2003. University of Queensland, Australia: Centre for Efficiency and Productivity Analysis, School of Economics. Cited in Krishna.

Dholakia, Bakul H. 2001. "Sources of India's Accelerated Growth and the Vision of the Indian Economy in 2020". *Indian Economic Journal*. Vol.49, No.4.

King, David A. 2004. "The Scientific Impact of Nations: What different countries get for their research spending", *Nature*, Vol. 430.

Krishna, K.L. 2004. "Some Aspects of Total Factor Productivity in Indian Agriculture". Paper presented at the conference in honour of Professor C.H. Hanumantha Rao, held on November 16-17 at Hyderabad.

Kumar, P. and M. Hossain. 2004. "Agriculture Development in South Asia". In R. E. Evenson, P. Pingali and T.P. Schutlz (eds.) *Handbook of Agricultural Economics: Agricultural Development: Farmers, Farm Production and Farm Markets* (mimeo). Cited in Krishna.

Martin,W. and D. Mitra. 2001. "Productivity Growth and Convergence in Agriculture versus Manufacturing". *Economic Development and Cultural Change,* Vol.49, No.2. Cited in Krishna.

Mashelkar, R.A. Undated. *Technology Achievement Index and Human Development.* Mimeo.

Mashelkar, R.A. 2005. "Global Voice of Science: India's R&D: Reaching for the Top". *Science,* Vol.307, Issue 5714, 1415-17.

Rao, D.S.P. and T.J. Coelli. 2004. "Catch-up and Convergence in Global Agricultural productivity." *Indian Economic Review*, vol. 39 (1), 123-48. Cited in Krishna.

Sivasubramonian, S. 2004. *The Sources of Economic Growth in India: 1950–51 to 1999–00.* New Delhi: Oxford University Press.

Suhariyanto, K. and C. Thirtle. 2001. "Asian Agricultural Productivity and Convergence." *Journal of Agricultural Economics*. 52, 96-110.

Swaminathan, M.S. 2001. *Times of India,* 11 July.

United Nations Development Programme, 2001. *Human Development Report.* New York: Oxford University Press.

2

CROP HUSBANDRY*

2.1. Introduction

The majority of the Indian people live in villages. Agriculture continues to be the major activity in rural areas of India and a substantial section of people are dependent on agriculture for their livelihoods. Apart from being a major provider of employment, the agricultural sector undoubtedly plays a crucial role with regard to the food security of the nation. Given this, factors contributing to agricultural production continue to remain central to the developmental concerns of the Indian economy. Adoption of modern technology in crop cultivation is a very important feature of agricultural development in Independent India. The varietal improvement programme, focusing on development of superior crop varieties through plant breeding, has been a vital component of modern agricultural technology. As the improved crop varieties performed effectively only in combination with fertiliser and water, the development of varieties necessitated the development of the agricultural input sector too. Apart from catalysing the input sector, the varietal improvement programme triggered several changes in cultivation practices, including land preparation, crop protection, use of agricultural machinery, processing, etc. Thus, the modern technology introduced in agriculture is often referred to as a package programme or seed-fertiliser-water technology or Green Revolution technology. In view of the pivotal role played by the varietal improvement programme in bringing about rapid changes in the crop production system as a whole, this is considered the most important technological intervention, or the catalytic technological intervention in the sphere of crop production in post-Independent India. Having identified the varietal improvement programme as the catalytic technology that has brought about significant changes in the crop production system, this chapter attempts a detailed analysis of technological interventions with regard to some selected crops: rice and wheat among major cereals, maize and sorghum among nutritious millets, soybean and sunflower among oil seeds, potato among vegetables, sugarcane and cotton among non-food crops.

This chapter is organized as follows: Section 2.2 provides a brief overview of developments in the crop husbandry sector as a whole in post-Independent India. Section 2.3 analyses the technological interventions with regard to nine crops and section 2.4 provides the concluding observations.

2.2. A Brief Overview of the Crop Husbandry Sector

At the time of Independence, productivity in agriculture was very low, and India relied heavily on food imports from the United States of America under the PL-480 scheme. During the first half of the century,

*Contributed by Dr. R. Rukmani, Principal Scientist, and Ms. N.Thenmathi, Project Associate, M. S. Swaminathan Research Foundation, Chennai, with inputs from Dr. C. Surendran, Former Director, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore.

growth of output in agriculture averaged slightly less than 1 % per annum while over the second half of the century it rose to slightly less than 3 % per annum. Over the years 1950–51 to 1999–2000, output growth in agriculture was largely related to growth in yields per hectare of cultivated area rather than expansion of area (Vaidyanathan 2004; Kapila 2004). The rapid growth in agricultural output in the post-Independence period is undoubtedly related to the technological development of agriculture in this period. During the mid 1960s, in order to achieve self-sufficiency in foodgrains, the Government of India decided to spread the cultivation of semi-dwarf high yielding varieties (HYV) of wheat and paddy, based on germplasm received from the International Maize and Wheat Improvement Centre (CIMMYT), Mexico, and the International Rice Research Institute (IRRI), the Philippines (Swaminathan 1993). Moreover, institutions such as the Commission on Agricultural Costs and Prices and the Food Corporation of India were set up to ensure remunerative prices to farmers, to maintain buffer stocks, and to contain the prices for consumers. Strategies were initiated to improve input supply, credit and marketing. Further, strengthening the agricultural research system has been one of the important development strategies in post-Independent India.

Agricultural R&D in India remains essentially in the public domain.[1] A system of research, education, training and extension in the field of agriculture (initiated by the colonial government) was expanded, strengthened and integrated during the post-Independence period. The National Agricultural Research System (NARS) functions in two tiers, one at the central level and another across different States. At the central level, the Indian Council of Agricultural Research (ICAR) is the apex body responsible for the organisation and management of research and education in all disciplines of agricultural sciences.[2] At the other level, the State agricultural universities (SAU), who are overseen by the State governments, address State-specific problems. In 1957, All India Co-ordinated Research Projects (AICRPs) were initiated under ICAR. AICRPs, considered an important intervention in agricultural research in India, are involved in building nation-wide co-operative, inter-disciplinary research networks linking the ICAR institutes with the SAUs to focus attention on specific crops (or commodities) of national importance. They carry out multi-location development and testing of new technologies and varieties. By 2004–05, 91 AICRPs and networks with 40 SAUs had been created. Apart from strengthening the research base in agricultural universities, AICRPs for some crops (e.g., rice and wheat) were elevated to the level of Project Directorates with additional research responsibilities. From **Table 2.1**, it is evident that ICAR directly administers 48 central research institutes (CRI), 31 national research centres, 5 national bureaux and 12 project directorates.

[1] Details on the agricultural research system in India are drawn from National Commission on Farmers (2005) and various publications of ICAR.

[2] The Imperial Council of Agricultural Research, established in 1929, was renamed as the Indian Council of Agricultural Research (ICAR) in post-Independent India.

Table 2.1: ICAR Institutions, 2004-05

Division	Institutes	National Bureax	National Research Centres	Project Directorates
Crop Science	10	2	7	6
Horticulture	10		12	
Animal Science	7	1	7	4
Fisheries	6	1	1	
Natural Resources Management	8	1	3	1
Agricultural Engineering	6			
Agricultural Extension			1	1
Agricultural Education	1			
Total	48	5	31	12

Source: ICAR (2006)

CRIs have been set up with a mandate to carry out basic and applied research on a single crop or on selected group of crops or on a geographic area or on a specific issue. Most CRIs have a network of regional stations covering diverse agro-ecological areas for developing area-specific technologies. The National Research Centres, on the other hand, have been established to work with a mission approach, on a particular crop (for instance, sorghum, soybean, groundnut, etc). ICAR has established 5 national bureaux to collect, conserve, evaluate and document genetic resources of crops, animals, fish and soil. Transfer of technology in the ICAR system is through the establishment of Krishi Vigyan Kendras (KVKs), where the technical literacy of farmers is improved through front-line demonstrations and on-farm testing. There were 496 KVKs across the country by 2004–05. ICAR is also involved in bilateral collaborative research programmes with national research organisations such as the Bhabha Atomic Research Centre, the Council for Scientific and Industrial Research, the Indian Council of Medical Research, the Indian Space Research Organisation, the Department of Biotechnology (under the Ministry of Science and Technology, Government of India), etc., and has Memorandums of Understanding (MOUs) with several institutes of the Consultative Group of International Agricultural Research (CGIAR).

With the establishment of infrastructure for systematic research in crops, research efforts have been directed towards developing varieties in almost all crops in India. The Central Variety Release Committee (CVRC), set up under the Ministry of Agriculture, receives proposals for release and notification of varieties from breeders, through their respective institutes under ICAR or SAUs.[3] CVRC scrutinises the performance of a variety and if it is found suitable for more than one State, it is then released as an improved variety for the country as a whole. If a variety is suitable only for one State, it is then released as a State variety by the respective State agricultural university.

[3] The word breeders refers here to State or Central departments or institutions that are licensed to produce breeder seeds.

The varietal improvement programme, considered to be the lifeline for overall R&D through the all India coordinated research programmes, has over the years concentrated on almost all major and minor cereals, pulses, and non-food crops. Various plant breeding techniques have been used to develop varieties and hybrids of crops with desirable characteristics such as high yield and improved quality as well as resistance to biotic and abiotic stresses. Most of the breeding programmes aim at improving crop yields, which is achieved by developing more efficient genotypes. Quality parameters taken into account during the varietal improvement programme vary across crops. For instance, the programme aims at improving the grain size, colour, milling and baking qualities in wheat, the cooking quality in rice, and the protein content in pulses. The development of resistant varieties of crops for abiotic (salinity, drought etc.) and biotic stresses (pests and diseases) is an important feature undertaken for almost all crops. Breeding for different maturing varieties is also an important objective in the varietal improvement programme of crops. For example, development of late maturing varieties of wheat has permitted rice-wheat rotation. The development of photoinsensitivity, which permits the cultivation of crops in non-traditional areas in crops, is also an area of interest.

The ICAR system, with its elaborate network of research activities, has developed and released more than 3300 high yielding varieties and hybrids pertaining to various crops (ICAR 2006). Over the five decades from 1951–52 to 1999–2000, area under cultivation as well as area irrigated has increased: while net sown area has increased by 21 million hectares, net irrigated area has increased by 35 million hectares. (**Table 2.2**) Increase in gross cropped area is of the order of 56 million hectares, indicating the rapid increase in cropping intensity from 1.11 in 1951–52 to 1.34 in 1999–2000.[4] Development and release of short duration varieties in various crops has certainly contributed towards an increase in double or multiple cropping, resulting in a rise in cropping intensity. Cultivation of high yielding varieties require an expansion of assured irrigation. Net irrigated area increased by 10 million hectares over 1951–52 to 1971–72, and in the next two decades it increased by about 18 million hectares. In the 1950s and ’60s, less than one-fifth of gross cropped area was under irrigation; this rose to two-fifths by the late 1990s.

Table 2.2: Area under Cultivation and Irrigation in India, 1951-52 to 1999-00

(million hectares)

Triennium centred around the year	Net Sown Area	Gross Cropped Area	Net Irrigated Area	Gross Irrigated Area
1951-52	120.53	134.26	21.01	23.01
1961-62	134.98	155.25	25.07	28.63
1971-72	139.04	164.38	31.49	38.56
1981-82	140.72	174.04	39.97	51.01
1991-92	142.45	184.56	49.32	64.97
1999-2000	141.59	190.43	55.98	76.92

Source: www.indiastat.com

[4] Chapter 3 discusses in detail the nature of expansion of irrigation in the country.

With the adoption of high yielding varieties, consumption of fertilisers in the country as a whole increased rapidly, from 13 kg per hectare on an average in 1970–71 to 95 kg per hectare in 1999–00 (**Table 2.3**). While these figures pertain to chemical fertilisers, production and consumption of bio-fertilisers have also increased over the 1990s. According to data furnished by the Fertiliser Association of India, consumption of biofertilisers in the country as a whole increased from 1600 tonnes in 1992–93 to 6300 tonnes in 1995–96 and 6700 tonnes in 1998–99 (www.fao.org).

Table 2.3: Fertiliser Consumption in India, 1951-52 to 1999-2000

Year	Consumption of Fertiliser Per Hectare of Gross Cropped Area (in kg)
1951-52	0.50
1955-56	0.89
1960-61	1.91
1965-66	5.06
1970-71	13.13
1975-76	16.90
1980-81	31.95
1985-86	47.48
1990-91	67.55
1995-96	74.02
1999-2000	95.23

Source: Reserve Bank of India (2003-04)

Apart from an increase in the use of chemical fertilisers, the other major change experienced in Indian agriculture has been the use of machinery for various agricultural practices. Over the three decades 1971–72 to 2002–03, the adoption of different types of power-operated agricultural machinery has increased (**Table 2.4**). The number of power sprayers and dusters used for fertiliser and pesticide spraying has increased 17 times over the three decades. Machineries used for ploughing — cultivators, disc harrows, mould board ploughs, etc. — have also increased rapidly. The number of threshers has increased nearly eightfold over the 30 years.

Table. 2.4: Growth of Power-operated Agricultural Machinery, India

Agricultural Machinery	Number (in '000s)			
	1971-72	1981-82	1991-92	2002-03*
Power sprayers and dusters	44.8	123.9	277.1	779.0
Mould board ploughs and disc ploughs	57.3	142.9	498.9	748.8
Disc harrows	55.6	189.2	545.6	933.0
Cultivators	81.5	315.0	1155.8	1771.5
Seed drills / seed-cum-fertiliser drills	24.6	160.69	730.1	1011.0
Planters	8.5	30.5	64.3	114.0
Threshers	205.8	1025.0	1379.3	1568.4

Note: * Tentative figures
Source: ICAR (2006)

Table 2.5: Growth of Tractors and Power Tillers, India

Particulars	Number (in '000s)				
	1961	1971	1981	1991	2003*
Tractors	31.00	148.00	518.00	1318.00	2361.20
Power Tillers	-	16.41	32.40	60.32	279.30

Note: * Tentative figures
Source: ICAR (2006)

The number of tractors in the country has increased nearly sixteenfold over the three decades since 1971. From about 1.4 lakh tractors in 1971, the number rose to 5.1 lakhs in 1981 and to 23.61 lakhs in 2003 (**Table 2.5**). While there has been a rapid spurt with regard to the number of tractors, the availability of tractors per hectare of gross cultivated area continues to be low: even by the mid 1990s, there was just one tractor per 100 hectares of gross cropped area (GCA).[5] The number of power tillers increased from 16,410 in 1971 to 2,79,300 by 2003.

Various inputs — seed, water, fertiliser and machinery — have had a tremendous impact on area under cultivation (**Table 2.2**), production and yield of crops (**Tables 2.6** and **2.7**). A significant achievement in adopting high yielding varieties has been the quantum jump in yield of crops, leading to a corresponding increase in agricultural output in the country. Foodgrain production increased from around 54 million tonnes in the early 1950s to about 195 million tonnes by the late 1990s. Within foodgrains, production of cereals increased fourfold while the progress made by pulses has been very marginal. Major non-food crops, such as oilseeds, sugarcane and cotton lint, have also registered a rapid boost in production, increasing at an annual compound growth rate of more than 2 % over 1951–52 to 2001–02. While the progress in production over the 1950s is related to improvement in irrigation and other associated development in the country, the later spurts are due to improvement in crop varieties of major foodgrains as well as of major non-food crops. **Table 2.6** further suggests that the rate of growth of production has declined across all crops during the 1990s compared to the 1980s. The rate of growth of foodgrain production per annum declined from 2.94 % in the 1980s to 1.09 % in the 1990s and that of sugarcane from 3.15 % to 1.99 % while oilseeds and cotton lint registered an absolute decline in production in 2001–02 compared to 1991–92.

Table 2.6: Production of Foodgrains and Major Non-Food Crops, India

(million tonnes)

Triennium centred around the year	Total Cereals	Total Pulses	Total Food grains	Total Oilseeds	Sugarcane	Cotton Lint*
1951-52	45.33	8.67	54.00	4.97	56.56	3.22
1961-62	69.63	12.00	81.63	7.22	101.96	5.33
1971-72	92.60	10.94	103.54	8.62	121.60	5.82
1981-82	119.47	11.33	130.80	10.48	176.71	7.47
1991-92	161.72	13.03	174.75	19.11	241.03	10.32
2001-02	182.96	11.86	194.81	17.98	291.58	9.41

Note: * Refers to production in million bales of 170 kg each
Source: www.indiastat.com

[5] 23.61 lakh tractors in 187 million hectares of GCA accounts to 1.26 tractors per 100 hectares of GCA.

From **Table 2.7** it is clear that the decline in the rate of growth of crop output over the 1990s is due to a decline in the rate of growth of yield of foodgrains as well as major non-food crops. The watershed decade has been the 1980s, when the rate of growth of foodgrain yield was the highest, at 3.16 % per annum.

Table 2.7: Yield of Foodgrains and Major Non-Food Crops, India, 1951-52 to 2001-02

(kg per hectare)

Triennium centred around the year	Total Foodgrains	Total Oilseeds	Sugarcane	Cotton Lint
1951-52	546	445	31,539	87
1961-62	699 (2.50)	494 (1.05)	42,961 (3.13)	117 (2.94)
1971-72	848 (1.95)	519 (0.49)	48,902 (1.30)	128 (0.93)
1981-82	1,030 (1.97)	578 (1.08)	57,497 (1.63)	160 (2.28)
1991-92	1,406 (3.16)	762 (2.81)	65,142 (1.26)	232 (3.79)
2001-02	1,641 (1.55)	811 (0.62)	66,825 (0.26)	190 (-2.02)

Note: Figures in brackets give the annual rate of growth of yield corresponding to the decade preceding the year of reference.
Source: www.indiastat.com

Increase in foodgrain production over the years has had a positive impact on per capita net availability of foodgrains in the country. In the early 1950s, per capita net availability of foodgrains was around 144 kg per year. This figure increased to 177 kg per year in the early 1990s. However, the deceleration in growth of foodgrain output in the 1990s has resulted in a sharp decline in per capita net availability of foodgrains to the tune of more than 50 gm / day over the 1990s (**Table 2.8**).[6] The sharp decline in the rate of growth of foodgrain yield from 3.16 % in the 1980s to 1.55% in the 1990s has serious implications for the nation's food security.

Table 2.8: Per capita Foodgrain Availability in the 1990s, India

Three-year Period ending in	Net Availability per Head			
	Cereals kg/yr	Pulses kg/yr	Foodgrains kg/yr	Foodgrains gm/day
1991-92	162.80	14.20	177.00	485
1994-95	160.80	13.50	174.30	478
1997-98	161.60	12.60	174.20	477
2000-01	151.70	11.50	163.20	447
Individual year				
2000-01	141.42	9.64	151.06	414
2001-02	146.76	11.61	158.37	434
2002-03	148.14	9.55	157.69	427

Source: Patnaik (2005a)

[6] The deceleration in growth of yield of two major cereals — rice and wheat — over the 1990s is responsible for the deceleration in growth of yield of foodgrains.

Though the 1990s has been a decade of agricultural decline, if one considers the entire period of five decades since 1950–51, land productivity as well as labour productivity have improved significantly in Indian agriculture.

Table 2.9: Labour and Land Productivity in Crop Husbandry, India, 1950-51 to 1999-2000

Year/Period	Value of output per worker in crop husbandry (Rs. at 1993-94 prices)	Annual compound growth rate of column 2	Value of output per ha in crop husbandry (Rs. at 1993-94 prices)	Annual compound growth rate of column 4
1	2	3	4	5
1950-51	5,464.40 (100)	-	4,880.20 (100)	-
1960-61	6,602.58 (121)	1.91	5,907.38 (121)	1.93
1970-71	7,214.68 (132)	0.89	6,974.24 (143)	1.67
1980-81	7,460.93 (137)	0.34	8,257.83 (169)	1.70
1990-91	9,011.95 (165)	1.91	10,390.28 (213)	2.32
1999-2000	10,571.72 (193)	1.79	12,713.85 (261)	2.27
1950-51 to 1999-2000		**1.36**		**1.97**

Note:
1. Growth rates correspond to the decade preceding the year of reference
2. Figures in brackets give the index w.r.to 1950-51
3. Number of workers in crop husbandry sector is estimated using the series provided by Sivasubramonian on number of workers in agriculture and allied activities, and the proportion of livestock workers to total agricultural workers in Census data.

Source: www.censusindia.net; EPW Research Foundation (2004); Sivasubramonian (2004)

The patterns of value of output per hectare and value of output per worker in agriculture over time clearly show an increasing trend and a rapid shift since the 1980s. Even while the Green Revolution techniques were being implemented from the mid 1960s, it is only with the rapid spread of these techniques from the 1980s that there has been an improvement in productivity. The increase in land productivity has been much higher than labour productivity from the late 1970s.

Using the value of output per hectare as an indicator, a technology achievement index for the crop husbandry sector has been calculated.[7] Value of output per hectare from agriculture, at 1993–94 prices, increased from Rs. 4,918 in 1951–52 to Rs. 6,809 in 1971–72, to Rs. 10,459 in 1991–92 and Rs. 12,613 in 1999–2000.[8] Considering that the value of output per hectare captures the improvement in crop yield as

[7] While value of output per hectare seen in constant terms would reflect the yield per hectare, the former has been chosen as the indicator of technology achievement rather than the latter. This is because we believe it is meaningless to combine the production of various crops, say, cotton, sugarcane and paddy, to work out overall yield of crops. Therefore, value of output per hectare which is expressed in monetary terms, and hence amenable to summation across crops, has been chosen as an indicator to measure technology achievement.

[8] Data refers to triennium centred around the years given and therefore is different from the individual year values given in Table 2.9.

well as the improvement in crop quality (and given that these aspects are influenced by technological interventions), this has been used as an indicator to measure technology achievement.[9] Using the time series of values of output per hectare, in constant prices, over 1950–51 to 2000–01, a simple index has been derived by keeping the triennium average of base period 1950–51 to 1952–53 as 100. **Figure 2.1** shows the pattern of technology achievement over the five decades since 1950–51; the value of the index has increased more than two-and-a-half times, from a base of 100 to 256.

Figure 2.1: Technology Achievement Index — Crop Husbandry

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

The important role of technology in agricultural growth in India has also been brought out by Sivasubramonian's (2004) meticulous estimation of total factor productivity for the agricultural and allied sectors as a whole (**Table 2.10**).

Table 2.10: Sources of GDP Growth in Agriculture and Allied Sectors, India

Particulars	1950-51 to 1960-61	1960-61 to 1970-71	1970-71 to 1980-81	1980-81 to 1990-91	1990-91 to 1999-2000	1950-51 to 1999-2000
Rate of growth of GDP from agriculture and allied sectors (%)	3.03	2.31	1.50	3.43	2.97	2.64
Contributions to GDP growth in percentage points						
1. Total Factor Input	1.38 (45.54)	1.43 (61.90)	1.85 (123.33)	1.54 (44.90)	1.29 (43.43)	1.51 (57.20)
2. Output per unit of input	1.65 (54.46)	0.88 (38.10)	-0.35 (-23.33)	1.89 (55.10)	1.68 (56.57)	1.13 (42.80)

Note: Figures in brackets give the percentage contribution of different components to GDP growth.
Source: Sivasubramonian (2004)

[9] Using the average wholesale prices prevailing in the primary markets during the peak marketing periods and the production estimates available from the Directorate of Economics and Statistics, the Central Statistical Organisation (CSO) estimates the value of output from crops. Value of output from agriculture includes all crop categories: cereals, pulses, oilseeds, sugars, fibres, indigo, dyes and tanning materials, drugs and narcotics, condiments and spices, fruits and vegetables, other by-products like straw and stalks (EPW Research Foundation 2004). This data along with area under crops has been used in this analysis to estimate value of output per hectare. Triennium averages of value of output per hectare have been arrived at for the period 1951–52 to 1999–2000. The methodology followed and data sources used to compute TAI for all other crops is similar to that of TAI for crop husbandry.

Discussing sources of growth in agriculture, Sivasubramonian (2004) notes: "The principal determinants of output are labour, capital and land. Growth in output can be achieved by increasing the resources used for production, that is, labour, capital and land or by increasing the output realised from the same quantity of resources. These are measured respectively by the total factor input and output per unit of input, that is, total factor productivity (TFP)." In the 1980s, when agriculture grew at 3.43 %, output per unit of input, or TFP, was the most important source of growth, accounting for 55 %. For the entire period from 1950–51 to 1999–2000, TFP accounts for 42.8 % of growth, and total factor input accounts for 57.2% of which labour input accounts for 34.5 %, capital 17.4 % and land 5.3 %. Therefore, for the entire period, TFP is seen as the most important source of growth in agriculture and allied activities. This clearly indicates the positive effects of science and technology in promoting agricultural growth.

While it is clear that technological interventions have had a key role to play in promoting agriculture, the extent of interventions as well as the exact nature of impact has varied across crops. The following section discusses the development of the varietal improvement programme with regard to nine crops, including the impact generated by the varietal improvement programme in terms of changes in yield, production, and per capita availability as well as value and output per hectare.

2.3 Analysis of Some Selected Crops[10]

The crop-wise analysis comprises of two parts: first, an analytical description of the development of the varietal improvement programme for the crop in the country; second, an analysis of various impact or outcome measures of the overall technological interventions on the crop pertaining to the country as a whole. While the first part deals directly with the catalytic technology, the second part of the analysis essentially captures the tangible benefits *triggered* by the catalytic technology. These benefits relate to enhancement of yield per hectare, improvement in production, quality and value of crop output as well as enhancement in per capita availability of crop output. Using the value of crop output per hectare as an indicator of technology achievement, an index of technology achievement over the years for the various crops has been worked out.

2.3.1 RICE

Rice is the most important cereal crop in India and is grown across the length and breadth of the country: under diverse eco-systems (irrigated, rainfed, coastal saline, hills), on a variety of soils, and under differing climatic and hydrological settings ranging from waterlogged and poorly drained to well-drained conditions. In 2000–01, rice accounted for nearly 42 % of foodgrain production in the country and was cultivated in more than one-third of the foodgrain area. Given the importance of rice in the foodgrain scenario of the country, breeders have paid considerable attention to improving its productivity and quality.

2.3.1.1 Varietal Improvement Programme[11]

Rice breeding efforts began in India around the early part of the 20th century, with the establishment of rice research stations in Dacca (now in Bangladesh) and Coimbatore. The Central Rice Research Institute

[10] Discussion on the varietal programme as well as the quantitative indicators of progress across crops is subject to the availability of data with respect to each crop.

[11] This section is based on Rai (2006); Rao et al. (1998); Rao (2004); Shobha Rani and Singh (2003).

(CRRI) was set up in Orissa in the year 1946. By 1950, there were 82 rice research stations in the country (Rai 2006). In the post-Independent period in India, one of the important development strategies was to strengthen the agricultural research system. As far as the rice varietal improvement is concerned, the Central Rice Research Institute (CRRI) in Cuttack and the Directorate of Rice Research (DRR) in Hyderabad are the most important research centres. DRR has the primary responsibility to coordinate research and development activities pertaining to rice crops through the All India Coordinated Rice Improvement Programme (AICRIP) that was initiated by ICAR in 1965. In 1966, the administrative control of CRRI was transferred to ICAR. Two research stations have been set up under CRRI: Central Rainfed Upland Rice Research Station (CRURRS) in Jharkhand and the Regional Rainfed Lowland Rice Research Station (RRLRRS) in Assam, to tackle the problems of rainfed uplands and flood-prone rainfed lowlands, respectively. Two Krishi Vigyan Kendras (KVKs) also function under CRRI. An effective collaboration between ICAR and the International Rice Research Institute (IRRI) has played a vital role in rice research in the country.

In colonial times, the rice research stations had developed a number of improved varieties through pure-line selections and hybridisation. In 1952, an inter-varietal hybridisation programme sponsored by the FAO aimed to combine the fertiliser responsiveness of *japonica* rice with the adaptability and quality of *indica* rice. However, none of these breeding programmes broke the yield barrier to any remarkable extent. The mid 1960s marked the introduction of the semi dwarf varieties, Taichung Native-1 from Taiwan and IR 8 from IRRI.[12] With this a major breakthrough in yield was achieved in India. Closely following the release of IR 8, the first Indian dwarf variety Jaya (developed by DRR) with as good a yield performance but slightly earlier in maturity was released in 1968. In heralding India's Green Revolution, the role of Jaya is as important as that of IR 8.

Intensive and continuous cultivation of semi-dwarfs caused disease and pest epidemics due to the identical genetic constitution of the varieties. This necessitated a shift in emphasis for the development of varieties with specific or multiple resistance to all the key pests and diseases. Identification of resistance source in W 1263, a derivative of native variety Eswarakora, and its use in cross-breeding resulted in a breakthrough in resistance breeding — the first gall midge resistant variety, Phalguna. The Central Variety Release Committee released Phalguna in 1978.

Quality improvement from the consumer angle was confined to fine grain white rice (Pusa 4-1-11), aromatic rice and red rice (Annapurna and TKM 9). As for aromatic rice, IARI came out with the world's first high yielding dwarf variety, Pusa Basmati 1, in 1989 (See Box 2.1).

ICAR initiated a programme on hybrid rice research and development in 1989 through a network of 12 active rice research centres across the country. In crop breeding, hybrid vigour is used in first-generation seeds (or F1). Hybrid rice uses a process called heterosis, which enables the offspring of two genetically diverse rice plants to produce more grain than either parent. While rice research is largely in the domain of the public sector, the private sector is also involved in the development of hybrid rice. Currently, the focus of rice research is on genetic and biotechnological approach to elevate yield frontiers and to improve grain quality and multiple resistances.

[12] Plant introduction: Taking a plant variety or species into an area where it has not been grown before

The All India Coordinated Rice Improvement Programme (AICRIP) helps in testing diverse genetic materials developed at national and international institutions. About 129 research stations across the country contribute breeding lines. 4841 breeding lines have so far been contributed by DRR and 1888 by CRRI. Till 2001, AICRIP has tested 17,544 entries and has organised 35 types of trials per year in 125 locations in 26 States in 5 regions. The entries tested in a particular year varied from 225 in the year 1967 to 1156 in 1975 and 678 during 2000 (Rao 2004). As a result of the various research efforts undertaken to improve rice cultivars, a total of 693 varieties and 18 hybrids have been released over the period 1965 to 2004.[13]

Box 2.1 Pusa Basmati 1

Research efforts have been on in India since the 1980s to develop high quality dwarf basmati varieties. Several aromatic varieties with medium to long slender grains were released by the late 1980s (Shobha Rani & Singh 2003). Scientists from IARI identified Pusa 615, a derivative of Pusa 150 / Karnal Local, through the step-wise convergent mode of improvement and selection procedure, and a sister selection of this was released as Pusa Basmati 1.

Bred by IARI and released for commercial cultivation in 1989, Pusa Basmati 1 is the world’s firstever non-lodging, semi-dwarf, high yielding basmati rice strain. With an average yield of 4.5 tonnes per hectare and maturing in just 135 days, Pusa Basmati 1 is a blend of the essential grain traits of traditional basmati rice (aroma, non-stickiness and elongation upon cooking) and the high yielding attributes of modern semi-dwarf varieties. Besides, being substantially photoinsensitive, it can also be grown outside its traditional territory. It has 1.0 to 1.5 t per ha yield gain over traditional varieties (Siddiq 1990).

“Basmati rice generates three times higher returns (US$800 to $1200 per tonne) than non-basmati rice ($200 to $400 per tonne) in both international and domestic markets. From a small beginning in 1978 / 79, when India exported 67,000 tonnes of basmati rice, earning a modest foreign exchange of Rs.3200 million, an upward swing continued and 1997 / 98 witnessed the highest volume of basmati rice exports with record foreign exchange earnings of Rs.16749 million. Pusa Basmati 1 is estimated to contribute roughly 60 per cent of the country’s total basmati rice exports,” say Krishniah and Shobha Rani (2000).

IARI released two new improved high-yielding basmati varieties in 2001: Pusa Sugandh 2 and Pusa Sugandh 3. They perform better in yield and the grains possess better aroma and lower chalkiness content. Moreover, they mature in just 120 days and are also more disease-resistant. Besides Sugandh 2 and 3, IARI has also developed Pusa RH-10, which is the world’s firstever superfine aromatic (basmati-like) hybrid rice, released in 2001 for commercial cultivation. The average yield of RH-10 (6 tonnes / ha) is even higher than that of the Sugandh varieties. Additionally, the maturity duration is lower at 115 days (*The Hindu Business Line* 27 September 2002).

[13] This section is largely based on the analysis of data collected from DRR in 2005. Three of the 18 hybrids were developed by private R & D but released by the CVRC.

Table 2.11 Release of Rice Cultivars in India

Period of Release	Varieties		Hybrids		Total number of Cultivars
	Number	Percentage	Number	Percentage	
1965-1970	24	3.46	Nil	-	24
1971-1980	128	18.47	Nil	-	128
1981-1990	222	32.03	Nil	-	222
1991-2000	244	35.21	14	77.77	258
2001-2004	75	10.82	4	22.22	79
1965 -2004	**693**	**100.00**	**18**	**100.00**	**711**

Note: Of the 18 hybrids, 15 have been developed in the public research system and 3 in the private sector.

Source: DRR (2005)

From **Table 2.11** it is clear that a remarkable increase in the release of varieties occurred during the 1980s and this momentum was maintained during the 1990s too. In the 1980s, 222 varieties were released as against 128 varieties in the earlier decade, while in the 1990s, the total number of released varieties at 243 was marginally higher compared to the 1980s. The 1990s have also been marked by the release of hybrids.

Table 2.12: Classification of Rice Varieties by Period of Release and Ecosystem

Period of Release	Varieties Released for different ecosystem		Percentage of varieties released		Ratio of irrigated to Rainfed varieties
	Irrigated	Rainfed	Irrigated	Rainfed	
1965-70	17	7	70.83	29.17	2.43
1971-80	84	44	65.63	34.38	1.91
1981-90	121	101	54.50	45.50	1.20
1991-2000	150	108	58.14	41.86	1.39
2001-04	50	29	63.29	36.71	1.72
1965-2004	**422**	**289**	**59.35**	**40.65**	**1.46**

Source: DRR (2005)

Table 2.12 makes it evident that, of the 711 rice varieties released over 1965–2004, 59 % or 422 varieties have been recommended for the irrigated ecosystem, while 41 % or 289 varieties have been released for the rainfed ecosystem.[14] Till 1980, the varietal improvement programme for rice focused on the irrigated ecosystem, with 65 to 70 % of varieties being released for irrigated areas. There was a change in this trend in the 1980s when 46 % of varieties developed were for the rainfed ecosystem.

[14] Of the cultivars released, 98 % are varieties and therefore it is perhaps not grossly incorrect to use the term ‘varieties’ instead of ‘cultivars’ in the discussion.

However, during the 1990s, the ratio of irrigated varieties to rainfed varieties increased, showing that varieties released were more for the irrigated areas. This is a matter of concern as, 46 % of area cultivated with rice has been classified as rainfed, even by year 2000–01.

Specific requirements of the irrigated ecosystem, taking into account varieties suitable for hill-irrigated systems as well as for the *boro* season, have been released in the 1990s. Varieties with fine grain and aroma have been given much importance since 2001, and as many as 16 scented rice varieties have been released in the period from 2001 to 2004, 7 being central releases and the rest by different States. Up to 2004, 21 varieties have been released for production in saline alkaline conditions.

Of the 711 varieties released from 1965 to 2004, 334 varieties were developed with resistance to diseases and 168 with resistance to pests. Development of disease-resistant varieties, which had always been important, received further impetus in the 1980s. Fifty-one per cent of all varieties released in the 1980s were resistant to one disease or the other, and 34 % of all disease-resistant varieties developed till 2004 have had their origin in the same decade. Development of pest-resistant varieties has also been significantly high since the 1980s. In the period 2001–04, the importance of developing and releasing varieties with pest and disease resistance has further gained ground.

Table 2.13: Classification of Pest- and Disease-Resistant Rice Varieties

Period of release	Number of rice varieties resistant to			Percentage of rice varieties resistant to		
	any disease	any pest	disease & pest	any disease	any pest	disease & pest
1965-70	9	1	1	37.50	4.17	4.17
1971-80	45	18	9	35.16	14.06	7.03
1981-90	113	52	33	50.90	23.42	14.86
1991-2000	109	48	27	42.25	18.60	10.47
2001-04	58	49	43	73.42	62.03	54.43
1965-2004	334	168	113	46.98	23.63	15.89

Note: Percentages are with respect to total varieties released in the period concerned.

Source: DRR (2005)

An analysis of disease-resistant varieties of rice indicates that breeders have concentrated on three major diseases affecting the crop: leaf blast, bacterial leaf blight and rice tungro virus. It is only in the late 1990s that two other diseases, neck blast and sheath rot, came into focus. Since the 1980s, the number of varieties developed with resistance to more than one disease has increased significantly.

In the years from 1965 to 1970, there has been only one pest-resistant variety and this was with respect to the brown plant hopper. In the 1970s, varieties resistant to 3 more pests (green leafhopper, stem borer, and gall midge) were released. During the 1980s, resistance to white-backed plant hopper and during the 1990s to leaf folder were developed in rice varieties. As in the case of diseases, in pests too, varieties with resistance to multiple pests increased over time. The number of varieties with resistance to both pests and diseases has been highest during the recent period, 2001-04.

Table 2.14 Classification of Rice Varieties by Type of Grain

Period of release of variety	Grain type		
	Bold	Slender	Total
1965-70	15	9	24
1971-80	51	77	128
1981-90	73	149	222
1991-00	117	140	257
2001-04	27	50	77
1965-04	283	425	708

Note: Grain type is not available for 3 varieties

Source: DRR (2005)

From **Table 2.14** it is evident that the proportion of varieties with slender grains was high during the 1980s and 1990s. Evenson (1999) summarises the important features of the rice varietal programme as follows: "Early modern varieties of rice released in India were bred in IRRI…Releases from 1965 to the early 1970s were the first generation IR-8 type semi-dwarf rices. Releases after the early 1970s were second generation types with disease and insect resistance incorporated systematically. Varieties released since the 1970s have incorporated more traits from Indian landrace materials."

Analysis of release of rice varieties over the recent decades indicates that a number of high points have been achieved during the 1980s. Varieties suitable for rainfed ecosystems, resistant to multiple pests and diseases, and scented and aromatic were released in large numbers during the 1980s. However, this by itself will not give the total picture of the progress of agricultural research, as adoption of varieties by the farmers is an important measure of the development of relevant technology. The availability of seeds of rice varieties as well as farmers' choice in the selection of seeds is a factor too. Given that there is no published official document giving details on area under specific high yielding varieties, an analysis of breeder seed production (BSP) data has been done to get an idea of the varieties accepted and demanded by farmers.[15] This analysis pertains to breeder seed production of varieties under the Indian Agricultural Research Institute's National Seed Project (NSP) and refers to a total of 7 years from 1997–98 to 2003–04.[16] It is important to keep in mind that over and above the production of breeder seeds under NSP, various States also produce breeder seeds and therefore an analysis of NSP without taking into account the production from the States will provide only a partial picture.[17] Analysing the data on breeder seed

[15] The Indian seed programme recognizes three generations of seeds in the seed multiplication chain: breeder, foundation and certified. Breeder seeds provide the source for the initial and recurring increase of foundation seed. Foundation seed is the progeny of breeder seed and certified seed is the progeny of foundation seed. After a variety has been notified, seeds of the variety can be certified and made available to farmers. Assessment of the requirement of seed is made at State level and based on this, production of foundation seed is organized by State agricultural departments, State seed corporations, National Seed Corporation, etc. The requirement of breeder seeds for producing the estimated quantity of foundation seed is made available to the Seeds Division of the Department of Agriculture and Cooperation in advance. The Seeds Division consolidates the seed indents from both public and private organisations and places the indents on ICAR, which in turn informs the breeders of the variety or hybrid to produce the required quantity (www.agricoop.nic.in).

[16] Data on BSP have been collected from the Annual Reports of the National Seed Project (Crops). Data from all the 26 institutes involved in breeder seed production of rice have been compiled in their respective annual reports.

[17] Even though the analysis of breeder seed production from NSP gives only a partial picture, its usefulness lies in the broad indicators it provides regarding demand for varieties.

production from NSP, it is evident that breeder seeds were produced for 59 % of the rice varieties that have been released. That is, of the 711 varieties that have been released up to 2004, a total number of 417 varieties attracted indents for breeder seed production. Breeder seeds were not produced for nearly 40 % or more of the total varieties released in any of the 7 years considered. The percentage of varieties that attracted breeder seed indent is much lower when we consider the individual years, in the range of 30 to 40 % of varieties only (**Table 2.15**).

Table 2.15 Breeder Seed Production for Rice Varieties, 1997-98 to 2003-04

Year	Number of varieties for which BSP was reported	Number of varieties released (up to that year)	Percentage of varieties with BSP
1997-98	204	579	35.23
1998-99	232	593	39.12
1999-2000	236	632	37.34
2000-01	234	663	35.29
2001-02	231	685	33.72
2002-03	259	700	37.00
2003-04	240	711	33.75
All 7 years	417	711	58.65

Source: IARI (1998-99 to 2004-05)

Table 2.16 indicates that out of 711 varieties released up to 2004, breeder seeds were produced for 97 varieties every year. These 97 varieties, referred to as stable varieties, account for about 14 % of all varieties released. About 72 of these 97 stable varieties have been those that were released during the 1980s and 1990s. It is significant to note that three varieties that were released in the 1960s — IR 8, Jaya, IR 20 — were indented for in all the seven years.

Table 2.16: Stable Rice Varieties

Period of release of varieties	Number of stable rice varieties	Names of rice varieties
1965-70	3	IR 8, Jaya, IR 20
1971-80	19	Mahsuri, Tellahamsa, Jyothi, Sita, Satya, Intan, Mangala, Kanchan, Kranti, Parijat, Prabhat, Surekha, Phalguna, Prakash, Rasi, PR 106, Swarnadhan, Sye 75, Sarjoo 52
1981-90	32	IR 36, Badava Mashuri, Govind, IR 50, Sona Mashuri, Swarna, Kalinga III, Pant Dhan 4, Savithri, Abilash, ASD 16, Pratibha, Samba Mahsuri, Vajram, White Ponni, ADT 37, ADT 38, IET 7191, Indrayani, Kanak, Rajshree, ADT 39, Chaityanya, CR 1014, Lalat, Pothana , IR 64, Kasturi , Krishnaveni , Pusa Basmati 1, Mukthi, Sye 1
1991-2000	38	ASD 18, Bahadur, Erranallelu, IR 30864, Kavya, Kushal, Ranjit, VL Dhan 221, Aathira, Aiswarya, HKR 126, Kairali, Khandagiri, Lunishree, Narendra 97, Pant Dhan 10, PNR 381, Jal Lahari, Narendra Dhan 359, Bhadrakali, Mahamaya, Pant Dhan 12, PR 111, RP 2421, Sugandha, Poornima, Vijetha, ADT 42, ASD 19 & 20, Indur samba, Keshava, Shiva, ADT 43, Luit, ADTRH 1*, CORH 2*, Early Samba
2001-04	1	KRH 2*
Others	4	Basmati 370, MDU 5, Sye 4, Sye 5

Note: * Hybrids: parental lines were indented
Source: IARI (1998-99 to 2004-05)

The maximum production of breeder seeds has been for varieties released during the 1980s, followed by the varieties of the 1990s in 6 out of the 7 years considered (**Table 2.17**). The demand for the 1960 varieties has been in the range of 2 to 5 % of total breeder seed production.

Table 2.17: Quantity of Breeder Seed Production

BSP pertaining to the year	Quantity of seed produced, classified by period of release of varieties (quintals)					Others*	Total quantity of BSP (quintals)
	1965-70	1971-80	1981-90	1991-'00	2001-04		
1997-98	225.31	910.13	2,622.38	1063.58	0.55	95.37	4,917.32
1998-99	257.17	1,072.96	2,543.51	1375.25	0.96	152.38	5,401.23
1999-2000	166.08	831.09	2,741.48	1993.3	1.46	254.8	5,988.21
2000-01	326.94	830.85	3,007.37	3,391.83	54.4	246.83	7,858.22
2001-02	299.97	970.07	2,794.81	2,622.65	94.3	87.84	6,869.64
2002-03	225.34	909.46	4,288.65	2,691.70	614.42	347.95	9,077.52
2003-04	238.22	944.32	2,785.82	1,969.04	862.06	221.18	7,020.64

Note: *Varieties for which year of release not available
Source: IARI (1998-99 to 2004-05)

According to a study conducted by Janaiah and Hossain (2004) across the 14 major rice growing States, only 221 rice varieties were adopted in the field in the period from 1998–2000. That is, the percentage of varieties adopted by the farmers in their fields accounted for 35 % of total varieties released till 2000. This study further notes that about 81 % of area under high yielding varieties of rice had adopted those varieties that were released in the two decades — the 1980s and 1990s.

2.3.1.2 Measures of Impact of Technological Interventions in Rice Production

Varietal improvement in rice has been instrumental in bringing about changes in the rice production system. The extent of adoption of HYVs, improvement in yield and the consequent changes in production, per capita availability and value of output are examined in this section.

a. Area under High Yielding Varieties of Rice

The impact of the introduction of high yielding varieties of rice crucially depends on the extent of adoption of these varieties. Area grown with high yielding varieties has increased more than fivefold over the three decades since 1970–71 (**Table 2.18**). About 15 % of rice-growing area was cultivated with HYVs in 1970–71. Over the 1970s, there was a trebling of area under HYVs and by 1980–81, more than two-fifths of rice fields was sown with HYVs. This expanded rapidly during the 1980s, to 64 % by 1990–91 and 73 % by the mid 1990s. However, the rate of increase slowed down over the late 1990s.

Table 2.18 Area under High Yielding Varieties of Rice, India, 1970-71 to 1996-97

Item	(Area in '000 hectares) Quinquennial averages centred around year					
	1970-71	1975-76	1980-81	1985-86	1990-91	1996-97
High Yielding Varieties	5,638	12,618	17,927	22,853	26,880	32,162
All varieties	37,590	39,480	40,150	41,140	42,690	43,466
Percentage of rice area cultivated with HYVs	15.11 (100)	32.45 (215)	45.04 (298)	56.14 (372)	63.69 (422)	73.99 (490)

Note: 1. Data on area under HYV for the years 1994-95 to 1996-97 are provisional and data for 1997-98 and 1998-99 are the target figures.
2. Figures in brackets give the index with regard to the year, 1970-71.
Source: www.indiastat.com

The percentage of area cultivated with high yielding varieties can be taken as a measure of the diffusion of technology. The index of the diffusion of technology worked out, using the adoption of HYVs as an indicator, shows an increase from a value of 100 in 1970–71 to 422 by 1990–91 and thereafter progressing slowly to reach 490 by the late 1990s.

As discussed earlier, there is no published data on area cultivated with specific high yielding varieties and the study done by Janaiah and Hossain shows that 56 % of rice area in the period 1998–2000 was cultivated with varieties that were resistant to pests and diseases. The emphasis laid by the rice varietal programme on improving the quality of grain has also had an impact on area cultivated with better quality grain: 77 % of the total area under high yielding rice varieties was cultivated with slender grain type (Janaiah and Hossain 2004). In 2002–03, hybrid rice was grown in approximately 2, 00, 000 hectares. (www.hybridriceindia.org / status.htm).

b. *Area under Irrigation*

In area cultivated with rice, the initial spurt in irrigation came about during the 1950s and again later during the 1980s and 1990s. However, even in 2001, nearly 46 % of the area cultivated with rice was under rainfed conditions. Rainfed rice is essentially cultivated in eastern India and north-eastern India. Lack of assured irrigation is an important reason for the slow development of area under high yielding varieties in rice.

c. *Fertiliser Consumption*

High yielding varieties of rice have been responsive to application of chemical fertilisers and there has been a tremendous increase in the use of fertilisers. Crop-wise consumption of fertilisers across States is collected under the comprehensive scheme that was initiated by the Ministry of Agriculture in 1971. Referred to as the cost of cultivation data, this is collected for 29 crops in 16 major States. Paddy cultivation is studied in 11 States and an analysis by Sen (2003) of fertiliser use for paddy over the period 1981 to 2000 shows a remarkable increase in the consumption of fertiliser per hectare. Five-year averages were calculated for three periods: 1981–86, 1988–93 and 1995–2000 and an average for the paddy crop for the country has been arrived at. Consumption of fertiliser in the country was 55 kg per hectare during 1981–86, 81 kg per hectare in 1988–93 and 99 kg per hectare in 1995–2000.

The progress in area under high yielding varieties of rice, increase in rice area under irrigation, and improvement in fertiliser consumption over the years have all impacted on several aspects of the rice production system.

d. *Area, Production and Yield of Rice*

From **Table 2.19** it is evident that lasting the five decades from 1951 to 2002, rice yield as well as rice production has increased significantly. Rice yield has more than doubled, rising from 764 kg per hectare in the early 1950s to 1980 kg per hectare in 2001–02. Rice production has registered an impressive growth, a more than threefold increase from about 23 million tonnes to 86 million tonnes, during the fifty years. Rice production and rice yields have been rising steadily from the 1950s onwards. Considering the entire period, the increase in rice production is largely due to improvement in yield while rice area has increased by 13 million hectares over the five decades. Over the entire fifty-year period, area under rice increased at an annual compound growth rate of 0.71 %, while the corresponding growth rate for rice yield has been 1.92 %. All through, growth rate of yield has been much higher than the growth rate of area except in the drought years of the mid 1960s.

Table 2.19 Area, Production and Yield of Rice, India

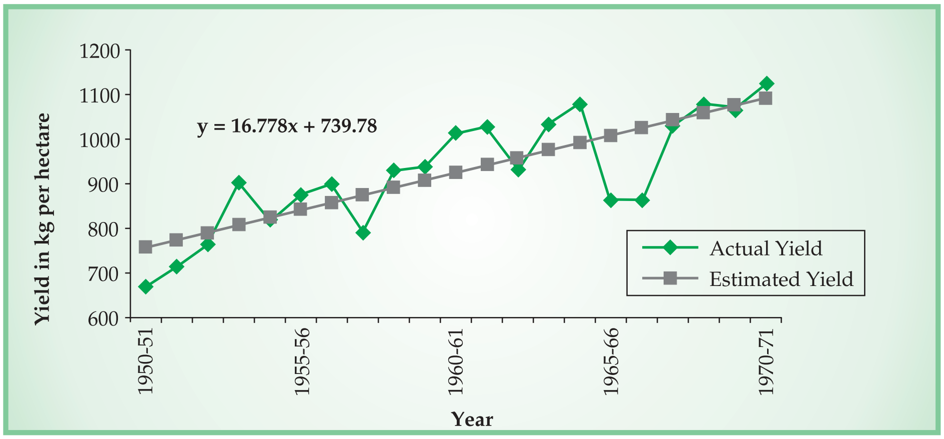
Quinquennial Average centred around the year	Area (million ha)	Production (million tonnes)	Yield (kg per ha)
1951-52	30.48 (100)	23.30 (100)	764 (100)
1961-62	34.83 (114)	34.43 (148)	988 (129)
1971-72	37.60 (123)	41.80 (179)	1,112 (145)
1981-82	39.96 (131)	51.29 (220)	1,281 (168)
1991-92	42.37 (139)	75.14 (322)	1,774 (232)
2001-02	43.46 (143)	86.09 (369)	1,980 (259)

Note: Figures in brackets give the index with respect to the base year 1951-52
Source: Ministry of Agriculture (various years)

The 1980s has been the watershed decade when rice yield registered a quantum jump from about 1281 kg per hectare to more than 1774 kg per hectare and production increased from nearly 51 tonnes in 1981–82 to about 75 tonnes in 1991–92. It has been observed earlier that as far as development of rice varieties are concerned, the 1980s has been a significant decade. It was also a decade when there was a rapid increase in area cultivated with high yielding varieties. The considerable progress in rice yield in the 1980s can be seen as a consequence of the great strides in the development and diffusion of technology during this period.

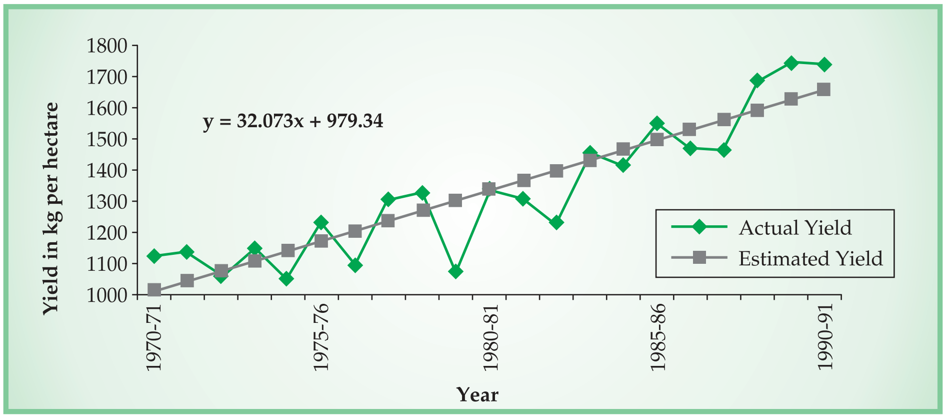
If a linear relationship between yield and time is postulated, then by regressing rice yields on time we can estimate the rate of change in yield for a unit change in time. Analysing the regressions for three time periods — 1950–51 to 1970–71, 1970–71 to 1990–91, and 1990–91 to 2000–01 — we find that the rate of change in yield was highest during the 1970s and ’80s, declining significantly in the 1990s. As can be seen from Figures 2.2, 2.3, and 2.4, and the regression equations, the annual increase in yield declined from 32 kg per hectare in the period 1970-71 to 1990-91 to 20.6 kg per hectare in the 1990s.[18]

Figure 2.2: Actual and Estimated Yield of Rice, 1950–51 to 1970–71



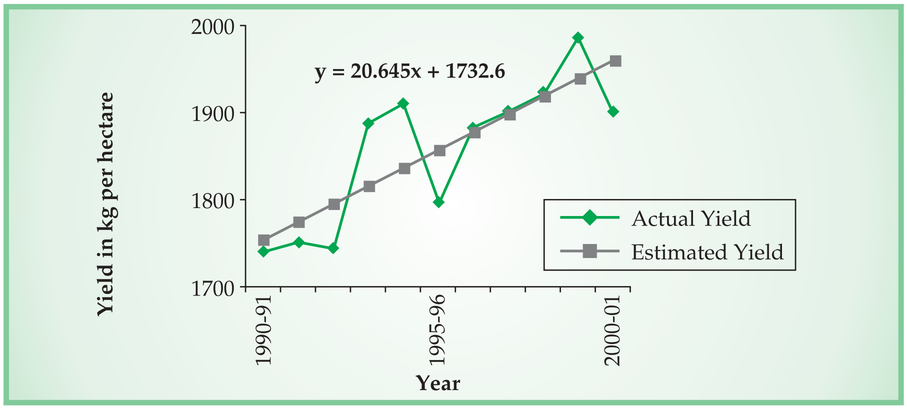
Source: Ministry of Agriculture (various years)

Figure 2.3: Actual and Estimated Yield of Rice, 1970-71 to 1990-91



Source: Ministry of Agriculture (various years)

Figure 2.4: Actual and Estimated Yield of Rice, 1990–91 to 2000–01



Source: Ministry of Agriculture (various years)

[18] The slopes of the three lines pertaining to the three time periods are significantly different at $p<0.05$; R square value for the 3 periods 1950–51 to 1970–71, 1970–71 to 1990–91 and 1990–91 to 2000–01 are 0.66,0.89 and 0.66 respectively.

The declining rate of increase in rice yield in the 1990s is related to the absence of any major breakthrough in development of new varieties with higher yield. A comment on the status of rice research from a report from the Directorate of Rice Research is quoted here: "………yield gains through conventional (hybridisation and selection) breeding methods have not been fully exploited. Even though variability for spikelet fertility / sterility, grain density and panicle components, etc. received considerable attention in the hands of geneticists and physiologists, and desirable types identified, they have not been systematically exploited in breeding programmes. Incorporation of some of these traits alone could result in measurable gains." (Rao et al. 1998) This point has been further reiterated by Nagarajan (1998): "In rice for the last twenty five years, no genotype has been developed with yield potential greater than IR 8 and Jaya. The new varieties developed for different rice-growing ecosystems in the post Green Revolution phase have not provided any genetic gain in yield. The major achievement of the program has been in developing varieties with shorter maturation, resistance to diseases, insect pests, grain quality and to abiotic stresses. The success has been in varietal diversity and quickly replacing the ones that become susceptible."

e. Per capita Net Availability of Rice

With the rapid increase in the yield of rice, the per capita availability has also improved over time. Gross production of rice declined in 1966 compared to 1961 due to the effect of droughts during the mid 1960s, and has increased steadily since then. Availability of rice grains per person also increased steadily from the mid 1960s, reaching the level of 81 kg per annum by the early 1990s. But there has been a steady fall since then and by the year 2000 per capita availability declined to 75 kg per annum. **Table 2.20** clearly shows an increase in per capita rice availability in the 1980s and a fall in the 1990s. In the years 1995–96 and 1999–2000, if net imports had been nil, per capita rice availability would have been higher by 3.56 kg and 1.43 kg respectively. But even this would have meant a decline from the 1990-91 level. The slowing down of rice production combined with the policy of exporting rice has very serious implications for per capita availability of rice in the country.

Table 2.20 Production and Availability of Rice, India, 1951-2000 (in '000 tonnes)

Year	Production		Net Imports	Change in Stocks	Estimated Net Availability	Per Capita net availability (Kg per annum)
	Gross	Net				
1950-51	22,058	20,382	761	70	21,073	58.02
1955-56	28,652	27,474	287	-540	28,301	71.23
1960-61	34,600	31,970	384	-121	32,475	73.41
1965-66	30,589	28,264	776	-107	29,147	59.10
1970-71	42,225	39,016	224	496	38,744	70.27
1975-76	48,740	45,036	206	2,963	42,279	68.50
1980-81	53,631	49,555	-254	-416	49,717	72.23
1985-86	63,825	58,974	10	-428	59,412	77.44
1990-91	74,291	68,695	-45	-339	68,989	81.01
1995-96	76,975	71,125	-3,344	-2,469	70,250	74.77
1999-00	89,475	82,675	-1,433	5,982	75,260	75.10

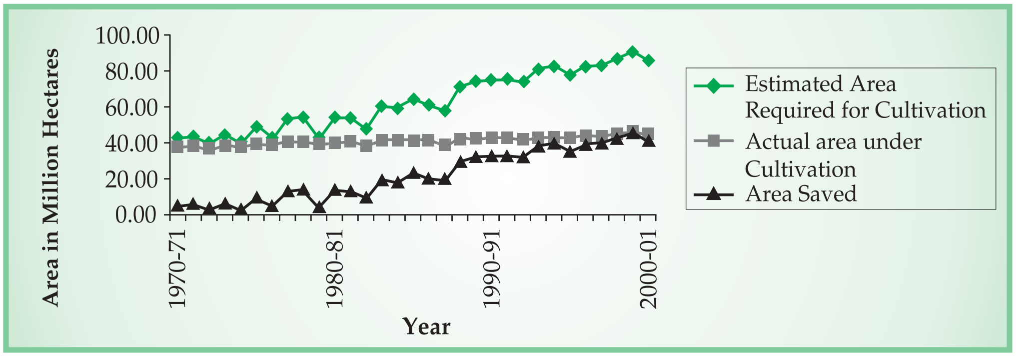
Note: Net imports=Gross Imports-Gross Exports; Change in Stocks refer to net increase or decrease in stocks at the end of the calendar year with FCI; Net availability is calculated as Net Production plus net imports minus change in stock; In estimation of per capita net availability, mid-year population as estimated by the Registrar General of India has been used.

Source: www.indiastat.com

f. *Area Saved Due to High Yields*

It could be argued that if high yielding varieties had not been introduced in rice and if yield levels had not increased, we would then have had to bring in more area under cultivation to reach the current level of production. Assuming that rice yield had remained unchanged at 990 kg per hectare (the three-year average yield level over 1966–67, 1967–68 and 1968–69), it is possible to estimate the area that would have been required to meet the rice production levels that have been attained. As this estimation procedure assumes that yield would remain constant and does not give any allowance for any increase in rice yield over the years, the estimate of area saved consequent to the introduction of HYVs will be an over estimation. As per this rough estimate, the area saved accounted for nearly 40 million hectares by the late 1990s. **Figure 2.5** illustrates the actual area under paddy cultivation, the area that would have been required to achieve current rice production levels with constant yield and the area saved due to achievement of high yields.

Figure 2.5: Estimate of Area Saved Due to High Yields in Rice

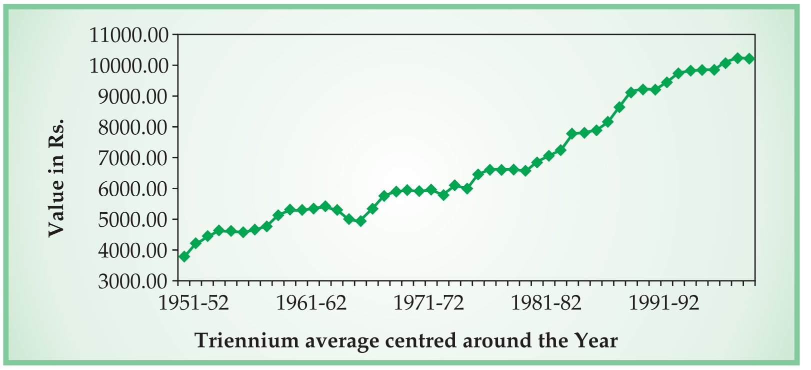


Source: Ministry of Agriculture (various years)

g. *Value of Paddy Output per Hectare*[19]

Value of paddy output, estimated in constant prices, has more than doubled from Rs. 3,785 per hectare in 1951–52 to Rs.10,205 in 1999–2000.(Table 2.21) Given that the value of output per hectare is in constant prices, an increase in per hectare value implies an increase in yield per hectare over time. There has been a sharp rise in per hectare paddy value since the mid 1970s. But, in the late 1990s the level of value of output per hectare has remained stagnant (**Figure 2.6**).

Figure 2.6: Value of Paddy Output per Hectare (at 1993–94 prices)



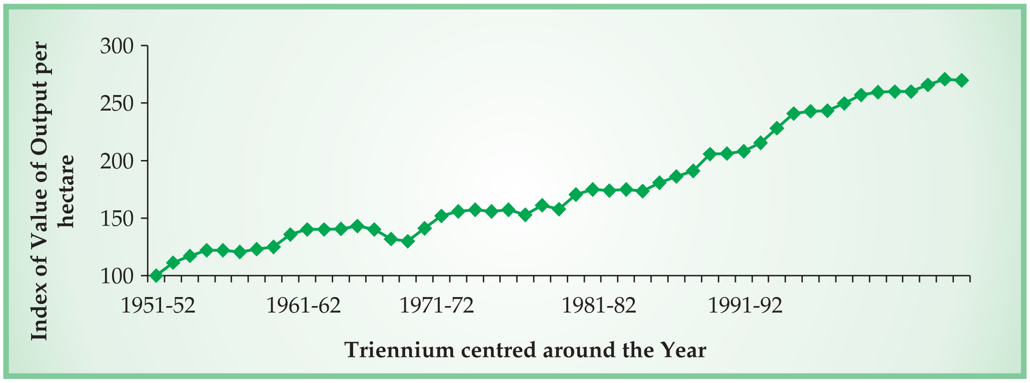
Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

[19] Data on value of output is available only for paddy and not rice

h. Technology Achievement Index — Paddy

Several outcomes triggered by technological interventions, more specifically the varietal improvement programme in rice, have been discussed above: changes in yield, production, per capita availability, value of output, etc. Of these, the value of output per hectare has been taken as an indicator of technology achievement. Using the time series of value of output per hectare of paddy, at constant prices over 1950–51 to 2000–01, a simple index has been derived by keeping the triennium average of base period 1950–51 to 1952–53 as 100. The value of the index has risen from 100 in 1951–52 to 156 in 1971–72, 181 in 1981–82 and 270 in 1999–00.[20] (**Figure 2.7**).

Figure 2.7: Technology Achievement Index — Paddy



Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

Table 2.21: Technology Achievement Index - Paddy

Triennium centered around the year	Value of output per hectare in Rs (1993-94 prices)	Technology Achievement Index
1951-52	3,784.65	100
1961-62	5,294.34	140
1971-72	5,891.88	156
1981-82	6,837.47	181
1991-92	9,199.76	243
1999-2000	10,205.55	270

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

Given that the value of output per hectare in constant terms reflects the yield per hectare, the stagnancy in the technology achievement index in the late 1990s is due to the sharp decline in rate of change in yield in this period.

2.3.2 WHEAT

After rice, wheat is the second most important cereal crop in India considering the contribution to total food grain production. In India, varietal improvement has played an important role in bringing about

[20] Given that Figure 2.7 is based directly on Figure 2.6, both figures exhibit a similar pattern.

rapid progress in wheat yield and production.[21] There are six wheat growing zones in the country classified on the basis of variations in environmental and growing conditions. **Table 2.22** provides details on the wheat-growing zones in the country. By the early 2000s, about 40 % of India's wheat area was in the north-western plains zone and another 33 % in the north-eastern plains zone.

Table 2.22: Wheat Growing Zones

Zone	Constitution
North-western Plains Zone (NWPZ)	Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions) and western Uttar Pradesh (except Jhansi division), parts of Jammu & Kashmir (Jammu and Kathua districts) and parts of Himachal Pradesh (Una district and Paonta valley) and Uttaranchal (Tarai region)
North-eastern Plains Zone (NEPZ)	Eastern Uttar Pradesh, Bihar, Jharkhand, Orissa, West Bengal, Assam and the plains of the north-eastern States
Central Zone(CZ)	Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan, and Jhansi division of Uttar Pradesh
Peninsular Zone (PZ)	Maharashtra, Karnataka, Andhra Pradesh, Goa, the plains of Tamil Nadu
Northern Hills Zone (NHZ)	Western Himalayan regions of Jammu & Kashmir (except Jammu and Kathua districts), Himachal Pradesh (except Una and Paonta Valley), Uttaranchal (except Tarai area), Sikkim and the hills of West Bengal and the north-eastern States
Southern Hills Zone (SHZ)	Hilly areas of Tamil Nadu and Kerala comprising the Nilgiri and Palani hills of the southern plateau.

Source: Shoran (2004)

2.3.2.1 Varietal Improvement Programme[22]

Wheat research began in colonial India in the early part of the 20th century at the Imperial Agricultural Research Institute (now known as the Indian Agricultural Research Institute – IARI), Pusa. During the first Five Year Plan period, 1951–56, a vast research network was established in the country to accelerate research on wheat. Research centres, with affiliation to IARI were established across the various wheat-growing zones of the country. State agricultural universities and State agriculture departments were also engaged in wheat research. ICAR initiated the All India Coordinated Wheat Improvement Project (AICWIP) in 1965. AICWIP, with its vast network of research centres in all the wheat-growing zones, plays a major role in wheat improvement by concentrating on different areas of research such as breeding, pathology, agronomy, quality, entomology, nematology and physiology. AICWIP organises multi-location yield trials for timely- sown and late-sown varieties under irrigated and rainfed conditions.[23] In 1978, this project was elevated to the level of the Directorate of Wheat Research (DWR). DWR has international collaborations with institutions such as the International Maize and Wheat Improvement Center (CIMMYT), Mexico; the International Center for Agricultural Research in Dry Areas (ICARDA),

[21] In 1968, the Government of India, in recognition of the impact of scientific wheat farming in the country, issued a postage stamp marked Wheat Revolution. This is depicted on the front cover of this report.

[22] This section is drawn from: Agrawal (1986); Nagarajan (2004); Rao (1978); Singh & Kulshrestha (1996); Swaminathan (1993); Tandon & Rao (1986).

[23] The timely-sown crop is seeded between 10 and 25 November while the late-sown variety is seeded between 10 and 25 December.

Syria; the United States Department of Agriculture; the International Rice Research Institute (IRRI), the Philippines; and the Australian Centre for International Agricultural Research (ACIAR).

Until the mid 1960s, improvement in wheat was confined exclusively to the tall varieties, which had the inherent limitation of lodging whenever intensive agricultural practices were followed (Rao 1978). Further, the rapid rise in temperature in February- March also imposed a ceiling on grain development and created problems of soil and atmospheric drought (Swaminathan 1993).

During the early 1960s, semi-dwarf varieties with lodging resistance were obtained from Mexico for field tests in India. Scientists in USA and Mexico had developed dwarf winter and spring wheat varieties, using one of the Norin wheats, namely Norin 10. In 1963 and 1964, four semi-dwarf varieties from CIMMYT, Mexico, were grown on a trial basis at different centres in India. Incorporation of Norin 10 dwarfing genes from these semi- dwarf varieties into the traditional varieties conspicuously improved wheat yields. The first semi-dwarf varieties released in India were pure-line selections from CIMMYT crosses. Out of different dwarf wheat obtained from Mexico, Sonara 64 and Lerma Rojo-64A were found superior with regard to adaptability and yield. However, these varieties did not become popular as the grains were red in colour. Subsequently, high yielding wheat like Kalyan Sona, Sonalika, etc., with amber or white grains, replaced them. Kalyan Sona, Safed Lerma, Sonalika and Chhoti Lerma, which were released in 1967, were selected from advanced breeding materials S 227, S 307, S 308 and S 331 received by the IARI from Mexico. From 1968 onwards, efforts were taken to produce multi-lines of commercial varieties, like Kalyan Sona, Sonalika and Sharbati Sonara, to prevent losses due to rust. Over the period 1965 to 2004, Central and State variety release committees have released 303 wheat varieties for commercial cultivation in the country.[24]

Table 2.23 Number of Wheat and Triticale Varieties Released in India Since 1965

Period	T.aestivum	T. durum	T.dicoccum	Triticale	Total
1965-1970	20	4	-	-	24
1971-1980	59	12	-	-	71
1981-1990	81	8	-	-	89
1991-2000	59	11	2	1	73
2001-2004	38	7	-	1	46
Total	257	42	2	2	303

Source: DWR (2005)

From **Table 2.23**, we find that 24 wheat varieties were released in the second half of the 1960s. The release of wheat varieties kept increasing rapidly in the subsequent decades and reached a peak of 89 varieties in the 1980s. In India, three wheat species are cultivated: *Triticum aestivum,* known as the common bread wheat, *Triticum durum* or macaroni wheat and *Triticum dicoccum* or emmer wheat. *Triticum aestivum*

[24] DWR holds annual workshops where the data generated from wheat trials conducted in different centres are discussed. All the information of the cultures presented by the concerned breeders along with control is put before a special committee of wheat scientists who examine the data and identify varieties that may be released. The central subcommittee on varietal release and notification is responsible for the release of varieties for specific areas and validating it through a gazette notification by the Ministry of Agriculture (Tandon and Rao 1986).

is the most important type grown and the bulk of varieties released belong to this species. Of the 303 varieties released from 1965 to 2004, 257 varieties or 85 % were *T. aestivum*, 42 were *Triticum durum* and 2 varieties were *T. dicoccum*. Two varieties of triticale, a cross between wheat and rye, were released after 1991. Of the 303 varieties released by 2004, 76 have been released specifically for the major wheat growing zone of the country, viz., the north-western plains zone comprising the Punjab, Haryana and western Uttar Pradesh (www.dacnet.nic.in).

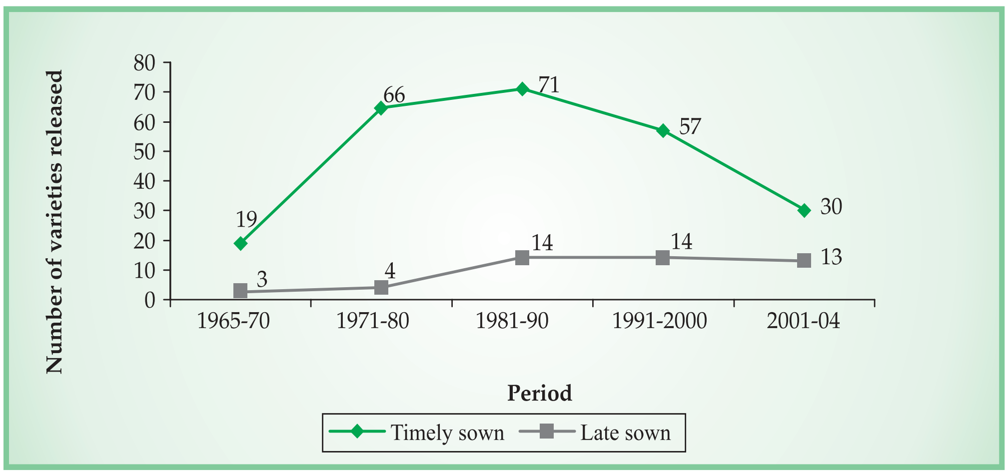
Table 2.24: Number of Wheat Varieties Released for Various Production Conditions

Period	Timely Sown				Late Sown		
	IR	RF	Misc.	Total	IR	RF	Total
1965-70	12	3	4	19	3	-	3
1971-80	44	18	4	66	4	-	4
1981-90	46	20	5	71	12	2	14
1991-2000	40	14	3	57	12	2	14
2001-04	19	8	3	30	13	-	13

Note: IR = irrigated; RF = rainfed; Misc = Miscellaneous timely-sown varieties that can be grown in irrigated or rainfed conditions; Varieties that can be grown either as timely sown or late sown or summer sown are not shown in the Table.

Source: DWR (2005)

Figure 2.8: Wheat Varieties Released for Different Production Conditions



Source: Table 2.24

From **Table 2.24**, it is clear that nearly 80 % of the varieties that have been released by 2004 are for timely-sown conditions.[25] However, release of varieties for late-sown conditions has been increasing since the 1980s. Most of the wheat crop in the country is under double / multiple cropping system and

[25] The late-sown crop is seeded between 10 and 25 December, while timely sown is seeded between 10 and 25 November. Rainfed wheat gets no irrigation and sowing is normally completed between 15 and 30 October, to take advantage of the receding moisture left behind by the monsoon (Mohan et al. 2001).

the late-sown programme has helped in raising cropping intensity, by making a slot for wheat in different crop sequences. (Sharma et al. 1998). Rice-wheat rotation is the principal crop sequence in our country, particularly in the Indo-Gangetic region. Wheat and rice varieties released during the Green Revolution period are photoinsensitive and short-duration crops and hence suited for the rice-wheat system over a large area (Singh and Paroda 1994). Increasing crop intensity has pushed more and more wheat area under late to very late sown situations (Sharma et al. 1998). In addition, delayed transplanting / sowing of rice results in delayed harvest of rice, and hence late sowing of wheat. Wheat varieties released for rainfed conditions account only for 22 % of the total released wheat varieties as wheat is mainly grown under irrigated conditions. Varieties are also released specifically for some wheat based products such as bread, biscuit, pasta and chapatti.

The germplasm repository established for medium-term storage of active collections at DWR maintains 8285 accessions of wheat. Almost all the continents are represented in the exotic germplasm. 5166 accessions have been sent to the National Gene Bank, NBPGR (National Bureau of Plant Genetic Resources), New Delhi for long-term conservation and 2841 accessions are conserved at Lahaul under cost-effective conditions (Shoran 2005).

Breeder seed production of wheat varieties under the National Seed Project has been analysed for the seven years from 1997–98 to 2003–04.[26] As in the case of rice, breeder seed for wheat varieties is produced in different States and therefore this analysis provides only a partial picture. The analysis indicates that in each year indents for breeder seed production have been received for one-third to two-fifths of varieties released. Considering all the seven years, a total of 176 varieties, that is, 58 % of all varieties released till 2003–04 have received indents for breeder seed production.[27]

Table 2.25 Breeder Seed Production for Wheat Varieties, 1997-98 to 2003-04

Year	Number of varieties for which BSP was reported	Number of varieties released (up to that year)	Percentage of varieties with BSP
1997-98	92	243	37.86
1998-99	89	249	37.54
1999-2000	86	257	33.46
2000-01	105	261	40.23
2001-02	109	283	38.52
2002-03	113	295	38.31
2003-04	116	303	38.28
1997-2004	**176**	**303**	**58.09**

Source: IARI (1998-99 to 2004-05)

[26] Data on BSP have been collected from the NSP Annual Reports, which provide data from 21 institutes involved in breeder seed production of wheat.

[27] Surprisingly, the acceptance rate of varieties (seen in terms of demand for BSP) for wheat and rice are very similar. See Table 2.15.

Table 2.26: Stable Wheat Varieties in India

Period of release of varieties	Number of stable varieties	Names of varieties
1965-1970	2	C 306, Sonalika
1971-1980	2	WH 147, HD 2189
1981-1990	16	Lok 1, Raj 1482, HD 2285, Sujata HI 617, DWR 39, HD 2329, HUW 206, WH 283, HUW 234, VL 616, PBW 154, HS 240, PBW 175, PBW 226, Raj 3077, GW 496
1991-2000	25	HPW 42, HS 295, Sonali HP 1633, WH 542, DWR 162, PBW 299, GW 173, DL 803-3 (Kanchan), DWR 195, HP 731 (Rajlaxmi), UP 2338, UP 262, VL 719, K 8962, K 9107, PBW 343, Raj 3765, HD 2643, HP 1744, PDW 233, VL 738, DDK 1009, DWR 185, HPW 89, HUW 468
2001-2004	None	Nil

Source: IARI (1998-99 to 2004-05)

Forty-five varieties or 15 % of total varieties released may be termed as stable wheat varieties that have attracted breeder seed production in all the seven years. While the bulk of the stable varieties have been released in the 1980s and 1990s, there are also 4 that belong to an earlier period. Analysing the quantity of breeder seed production, it is clear that the varieties released during the 1990s have been the most popular with regard to the number of varieties as well as quantity of seeds produced (**Table 2.27**).

Table 2.27: Quantity of Breeder Seed Production

BSP pertaining to the year	Quantity of seed produced (in quintals) of varieties classified by period of release of varieties					Others*	Total Quantity (in quintals)
	1965-70	1971-80	1981-90	1991-2000	2001-04		
1997-98	285.59	1,934.05	4,432.42	5,370.38	-	745.19	12,767.63
1998-99	348.90	1,754.50	4,517.58	6,033.35	-	62.00	12,716.33
1999-2000	349.29	2,092.15	6,120.96	7,723.86	-	61.90	16,348.16
2000-01	445.58	1,706.62	4,158.04	9,414.03	310.72	558.91	16,593.90
2001-02	278.63	748.22	3,892.16	7,956.29	597.55	259.63	13,732.48
2002-03	193.00	607.30	3,122.04	8,482.09	1,082.08	299.80	13,786.31
2003-04	412.38	580.70	4,097.04	9,462.50	2,184.88	1,308.39	18,045.89

Note: * Varieties for which year of release not available

Source: IARI (1998-99 to 2004-05)

2.3.2.2 Measures of Impact of Technological Interventions in Wheat Production

a. Area under High Yielding Varieties of Wheat

Adoption of high yielding varieties has been very rapid in wheat. While in 1966–67, just about 4 % of wheat area was grown with HYVs, this had increased to 35 % by 1970–71. **Table 2.28** provides the quinquennial averages of wheat area under HYVs for the period 1966–67 to 1998–99. By the late 1990s, nearly 90 % of wheat cultivated has been with HYVs.

Table 2.28: Area under High Yielding Varieties of Wheat, India

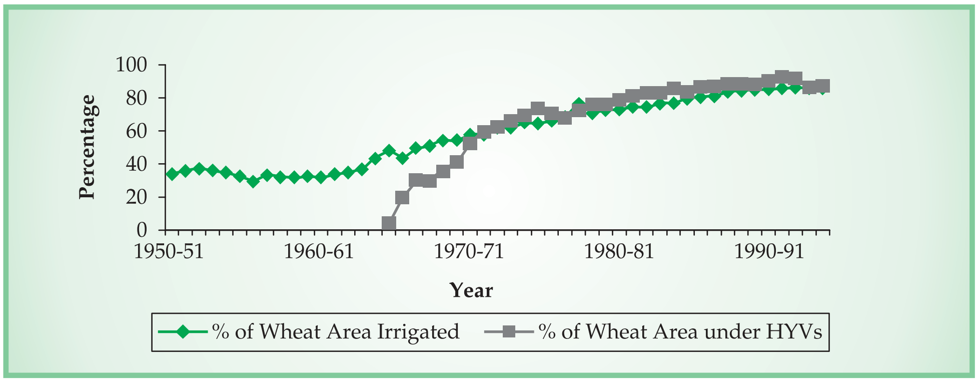
Item	(Area in '000 hectares) Quinquennial averages centred around year					
	1968-69	1975-76	1980-81	1985-86	1990-91	1996-97
Area under HYVs of wheat	3,933	13,201	16,324	19,287	20,736	23,399
Total area under wheat	15,732	19,884	22,560	23,484	23,926	26,164
Percentage of wheat area cultivated with HYVs	25.00 (100)	66.39 (266)	72.36 (289)	82.13 (329)	86.67 (347)	89.43 (358)

Note: 1. Data on area under HYV for the years 1994-95 to 1996-97 are provisional and data for 1997-98 and 1998-99 are the target figures; 2. Figures in brackets give the index with regard to the year 1968-69.

Source: www.indiastat.com; Ministry of Agriculture (various years)

b. *Area under Irrigation*

Figure 2.9: Pattern of Growth of Irrigation and HYVs



Source: www.indiastat.com; Ministry of Agriculture (various years)

Given that high yielding varieties perform well only under assured irrigation, and wheat is essentially grown in irrigated regimes, there is a very close correspondence between area under irrigation and area under HYVs (**Figure 2.9**).

c. *Fertiliser Consumption*

In the cultivation of a crop, the use of fertiliser is often considered an indicator of technology adoption. Using Sen's (2003) analysis of cost of cultivation data, it is found that among food crops, the highest per hectare fertiliser use has been in wheat. Further, five year averages for 1981–86 and 1995–2000 show that fertiliser consumption per hectare of wheat has steadily increased from 88 kg to 137 kg in the country as a whole. Sugarcane is the only crop that has a higher level of fertiliser consumption than wheat. The extent of adoption of high yielding varieties and the use of fertiliser in the cultivation of wheat clearly indicate the modernisation of production systems. The impact of modern methods of cultivation on yield, production, value and availability of wheat has been analysed in the following section.

d. *Area, Production and Yield of Wheat*

From **Table 2.29** it is evident that over five decades from the 1950s, production of wheat has increased more than tenfold, from 10.8 million tonnes in 1951–52 to 71.2 million tonnes in 2001–02. The major spurt in wheat production has come about since the 1960s, when the semi-dwarf varieties were adopted for cultivation. Wheat yield was 807 kg per hectare in the early 1960s and has since been increasing significantly. Considering the period 1951–52 to 2001–02, it is only in the first decade that increase in production was essentially due to increase in area cultivated. In all the other years, while there has been a significant expansion in area the rate of growth of yield has been higher than that of area cultivated.

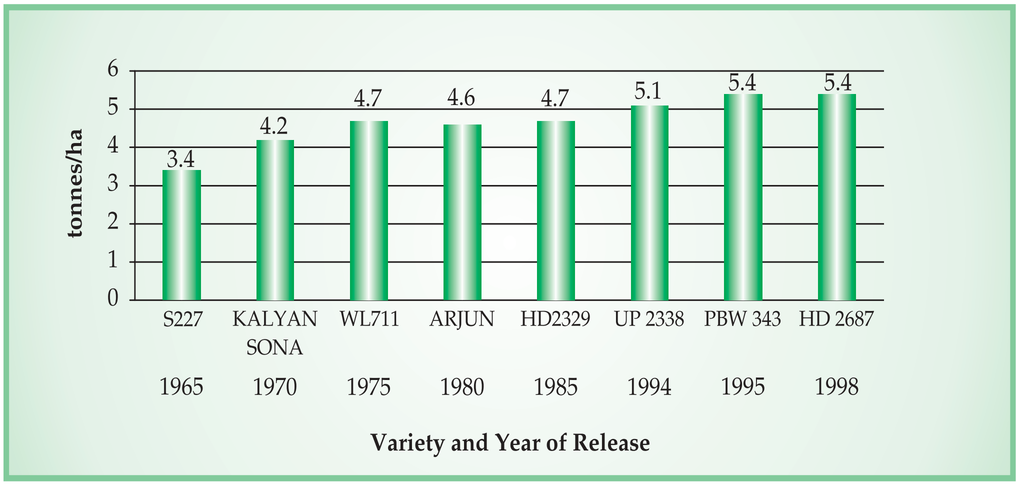
Table 2.29: Area, Production and Yield of Wheat in India

Quinquennial Average centred around the year	Area (million ha)	Production (million tonnes)	Yield (kg per ha)
1951-52	9.91 (100)	6.91 (100)	697 (100)
1961-62	13.39 (135)	10.80 (156)	807 (116)
1971-72	18.41 (186)	23.37 (338)	1,268 (182)
1981-82	22.97 (232)	38.77 (561)	1,683 (241)
1991-92	24.13 (244)	55.55 (804)	2,301 (330)
2001-02	26.21 (264)	71.20 (1030)	2,715 (389)

Note: Figures in brackets give the index w.r. to the base year 1951-52.
Source: Ministry of Agriculture (various years)

Over 1951–52 to 2001–02, area cultivated has been increasing at the rate of nearly 1.96% per annum while yield has increased at the rate of 2.76 % per annum, leading to a massive growth in wheat production. With the release of new genotypes, using crossed Indian and exotic germplasm, combining greater resistance to rusts and other diseases and larger per day production, the yield potentials of wheat varieties have been continuously improved. The 1960s saw the highest rate of growth in yield (4.17 % per annum) and this momentum continued in the 1970s and ’80s (2.88 % per annum and 3.17 %, respectively). The development of wheat varieties with improvement in yield as well as the adoption of these varieties during this period is clearly responsible for the observed pattern of growth of area, yield and production of wheat. The rate of growth in yield declined from 3.17 % in 1980s to 1.67 % in 1990s, as there had been no breakthrough in wheat varieties. According to Nagarajan (1998): “In India, with the sustained plant breeding efforts, continued increase in the productivity of wheat has been achieved over a period of time. Compared to Lerma Rojo 64, Kalyansona yielded better and WL 711 was an improvement over it. Later HD 2329, WH 542 and PBW 343 have registered better yields, one over the other. It can be said that there is a genetic gain of 1% in yield in a compound interest rate. And almost every decade there has been a quantum jump in yield due to plant breeding efforts. However, this is not the case in all crops.” In 2006, Nagarajan further comments: “No new superior variety has come in the recent 10 years.”

Figure 2.10: Genetic Gain in Wheat Yield

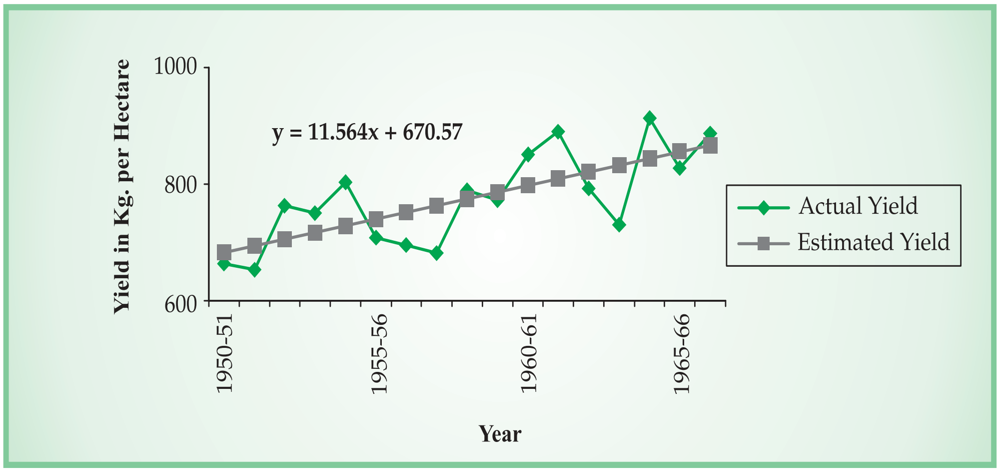


Source: Nagarajan (2004)

By the late 1990s, however, the plant breeding efforts seem to have reached a plateau.

If a linear relationship between yield and time is postulated, then by regressing wheat yields on time we can estimate the rate of change in yield for a unit change in time. Analysing the regressions for three time periods — 1950–51 to 1966–67, 1966–67 to 1990–91, and 1990–91 to 2000–01 — we find that the rate of change in yield was highest during the second period and declined significantly in the 1990s. As can be seen from **Figures 2.11, 2.12, 2.13** and the regression equations, the annual increase in yield declined from 50.39 kg per hectare in the second period to 43.54 kg per hectare in the third period, that is, the 1990s.[28]

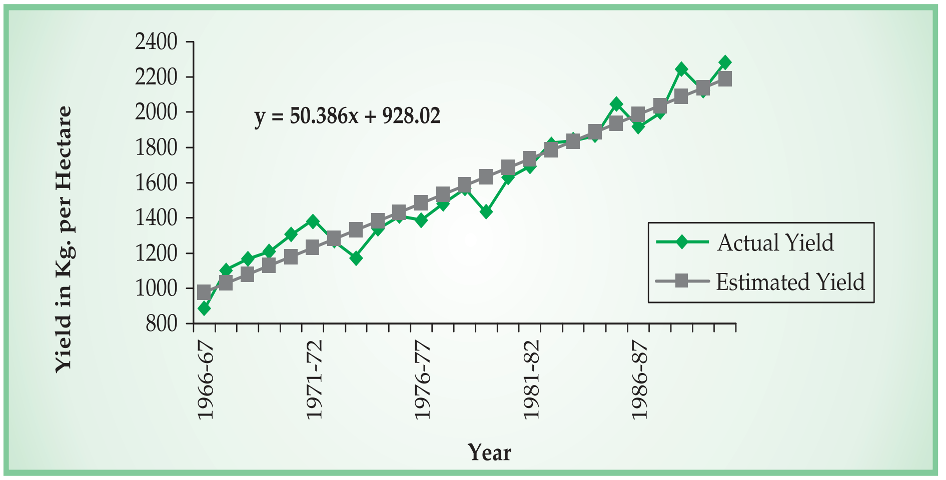
Figure 2.11: Actual and Estimated Yield of Wheat, 1950–51 to 1966–67



Source: Ministry of Agriculture (various years)

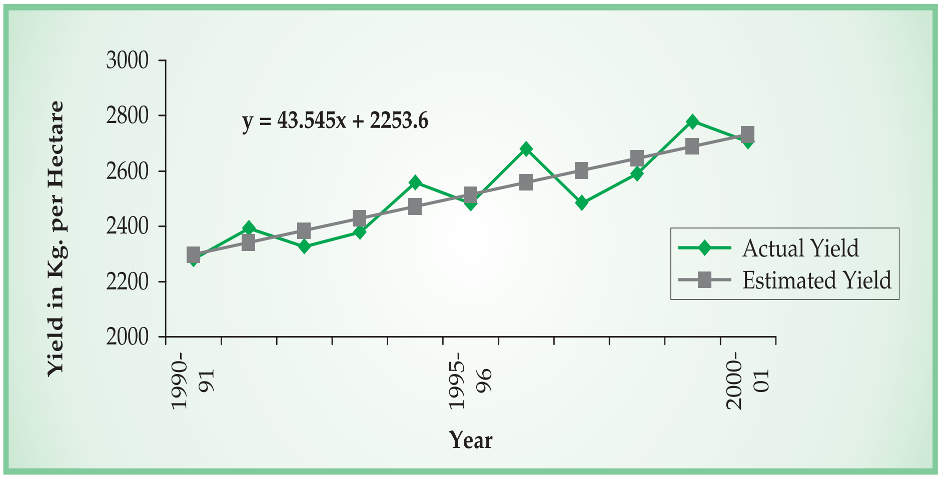
[28] R square value for the 3 periods — 1950–51 to 1966–67, 1966–67 to 1990–91 and 1990–91 to 2000–01 — are 0.52, 0.94 and 0.78, respectively. The slopes of the regression lines are significant at $p<0.05$.

Figure 2.12: Actual and Estimated Yield of Wheat, 1966–67 to 1990–91



Source: Ministry of Agriculture (various years)

Figure 2.13: Actual and Estimated Yield of Wheat, 1990–91 to 2000–01



Source: Ministry of Agriculture (various years)

The declining rate of increase in yield in the 1990s, as pointed out earlier, has been attributed to lack of development of varieties with genetic gain in yield. Other factors contributing towards this have been water scarcity and lack of moisture efficient genotypes, as well as increase in soil temperature (Nagarajan 2006).

e. *Per capita Net Availability of Wheat*

Table 2.30: Estimates of Net Availability of Wheat, India, 1950-2000

(in '000 tonnes)

Year	Production		Net Imports	Change in Stocks	Estimated Net Availability	Per Capita net availability (Kg per annum)
	Gross	Net				
1950-51	6,822	5,997	3,063	356	8,704	23.96
1955-56	8,869	7,796	1,104	-50	8,950	22.53
1960-61	10,995	9,665	3,090	-20	12,775	28.88
1965-66	10,394	9,136	7,827	-214	17,177	34.83
1970-71	23,832	20,948	1,811	1,914	20,845	37.81
1975-76	28,846	25,356	6	7,419	17,943	29.07
1980-81	36,313	31,919	777	172	32,524	47.25
1985-86	47,052	41,359	-68	-985	42,276	55.10
1990-91	55,134	48,464	-529	-3,942	51,877	60.91
1995-96	62,097	54,583	-150	-6,065	60,498	64.39
1999-2000	75,574	66,430	5	7,870	58,565	58.44

Note: Net imports=Gross Imports-Gross Exports; Change in stocks refers to net increase or decrease in stocks at the end of the calendar year with FCI; Net availability is calculated as net production plus net imports minus change in stock; In estimation of per capita net availability, mid-year population as estimated by the Registrar General of India is used.

Source: www.indiastat.com

Table 2.30 shows that the volume of wheat imports was on the high side and was growing till 1965–66; it has reduced drastically with the beginning of the wheat revolution in the mid 1960s. There has been a perceptible increase in per capita net availability of wheat over the years and the decline in 1975–76 is due to an increase in stocks with the Food Corporation of India. In 1990–91, about 5 lakh tonnes of wheat were exported, resulting in a slower rate of growth of per capita net availability. This increased by barely 5 kg per annum from 1985–86 to 1990–91. Exports of wheat continued in the first half of the 1990s and by 1999–2000, the stocks with FCI were as high as 7.8 million tonnes, resulting in a decline in per capita availability from 64 kg per annum in 1995–96 to 58 kg per annum in 1999–2000.[29]

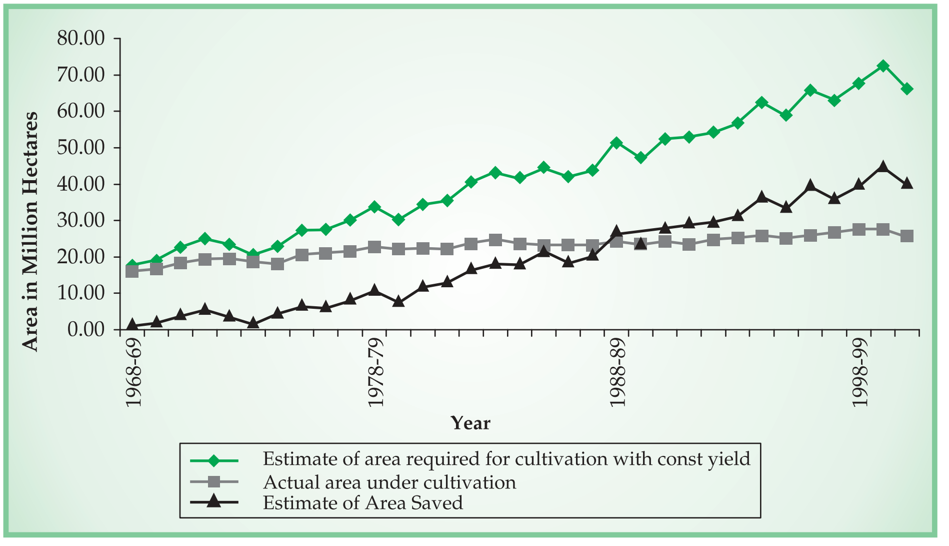
f. *Area Saved Due to High Yields*

An estimate of area saved due to adoption of high yielding varieties of wheat has been attempted, an exercise similar to the one undertaken with regard to rice. This exercise assumes that yield remains constant at 1053 kg per hectare (the three-year average yield for the years 1966–67 to 1968–69), over 1968-69 to 2000-01 and estimates the amount of area required to produce the current levels of production.

[29] For a critical analysis of government policy with regard to exports and the public distribution system, see Patnaik (2005b).

This rough estimate indicates that the area saved due to adoption of HYVs was in the range of 35 to 40 million hectares by the late 1990s. This however is an over estimation as yield is assumed to remain constant throughout. **Figure 2.14** indicates the actual area under wheat cultivation, the area that would have been required if wheat yield had stagnated, and the area saved due to achievement of high yields.

Figure 2.14: Estimate of Area saved due to High Yields in Wheat



Source: Ministry of Agriculture (various years)

g. *Value of Wheat Output per Hectare and TAI of Wheat*

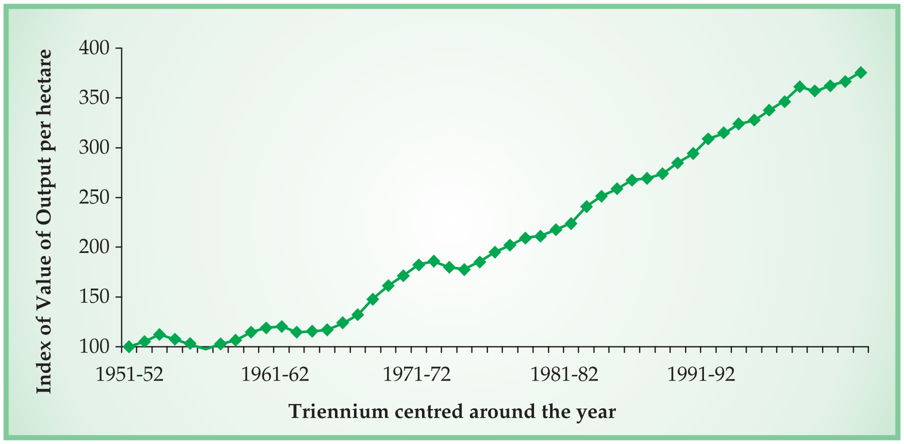
The monetary value of wheat output per hectare was less than Rs 3000 in 1951–52 (at 1993–94 prices). This has increased rapidly since the mid 1960s, going above Rs 5000 in 1971–72, and reaching Rs. 10,155 by 1999–2000. This rapid increase is understandable given the swift rise in wheat yield over the years. Using the time series data on value of output per hectare over the period 1950–51 to 2000–01, the technology achievement index (TAI) for wheat has been calculated. TAI of wheat increased from a base of 100 in 1951–52 to 375 in 1999–2000 (**Figure 2.15**).

Table 2.31: Technology Achievement Index - Wheat

Triennium centered around the year	Value of output per hectare in Rs (1993-94 prices)	Technology Achievement Index
1951-52	2,705.83	100
1961-62	3,253.17	120
1971-72	5,029.52	186
1981-82	6,515.78	241
1991-92	8,770.33	324
1999-2000	10,155.79	375

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

Figure 2.15: Technology Achievement Index — Wheat



Source: EPW Foundation (2004); Ministry of Agriculture (various years)

2.3.3 MAIZE

Maize is an important foodgrain as well as a feed crop in India. It is essentially a warm weather or *kharif* crop and as such is largely dependent upon the rains. While the main season for maize cultivation is *kharif*; it is also cultivated as a *rabi* crop and during *zaid* (or spring) in some parts of India. In most parts of India, *kharif* maize is sown with the break of the monsoon rains, the actual dates varying from region to region. Both the spring and the *rabi* crops are generally raised under irrigation. Maize can grow under diverse conditions from sea level to hot arid plains as well as in 3000 metre altitudes. It does, however, require considerable moisture and warmth from germination to flowering.

2.3.3.1 Varietal Improvement Programme[30]

Prior to 1950, no comprehensive research efforts for maize improvement had been made in India at the national level. Indian maize germplasm, in general, lacked the requisite degree of genetic diversity needed for the successful development of high yielding maize hybrids, even though some of the indigenous maize varieties were good. Since the early 1950s, research has been underway to develop and identify high yielding maize hybrids and composite varieties.[31] The Government of India introduced a number of commercial maize hybrids, mainly from the North American and Caribbean regions. But the direct introductions which were of dent grain type as the traditionally grown varieties are of flint grain type did not suit Indian conditions. Realising this, the government appointed a committee in 1953–54 to review maize improvement work in India. On the basis of the recommendations made by the committee, ICAR initiated the All India Coordinated Maize Improvement project (AICMIP) in 1957. This marked the beginning of an integrated and multidisciplinary approach to maize improvement. In 1994, this project was elevated as the Directorate of Maize Research (DMR). CIMMYT has been developing quality protein maize (QPM), using its own lines for cultivation in India.[32]

[30] This section relies heavily on DMR (2001 and 2004) and Singh et al. (2003). The analysis here pertains only to the developments in public-funded institutions.

[31] Varieties produced by open pollination among a number of outstanding strains usually not tested for combining ability with each other.

[32] For example: Indian QPM white hybrids Shaktiman 1 using (CML142 x CML150) x CML186 and Shaktiman 2 using CML176 x CML186; yellow QPM hybrids HQ-1 and HQ-2 in 2003 using CML 161 and CML 193.

The quality of maize protein is poor due to the presence of large concentrations of zein, an alcohol soluble protein fraction. Zein fraction is very low in lysine and tryptophan content and high in leucine content. QPM is an outcome of the efforts to breed vitreous endosperm backgrounds with better-balanced amino acid composition to meet nutritional requirements.

ICAR is involved in promoting and coordinating maize research and development throughout India through DMR's network, which comprises 27 research and three cooperating centres (at Rajori, Pahelgam and Ranchi), representing the five zones of India.

Table 2.32: Maize Growing Zones and Research Centres

Zone	State
Zone I (Hill region)	Jammu & Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, North-eastern States, North-west Bengal
Zone II (North-west & Central Plains region)	Punjab, Haryana, Delhi, Uttar Pradesh
Zone III (North-east Plains region)	Bihar, Jharkhand, Eastern Uttar Pradesh, West Bengal, Orissa
Zone IV (Peninsular region)	Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Goa
Zone V (Central India)	Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh

Source: www.maizeindia.nic.in

The development of maize research in India may be classified into three distinct phases (www.maizeindia.nic.in/history.htm). In the first phase (1957–1974), with the initiation of AICMIP, initial steps were taken to produce maize cultivars with high yield, resistant to pests and diseases, and improved in quality. In the second phase (1974–1989), early and very early maturing cultivars and winter maize were developed. In the third phase (1990 onwards), region specific maize cultivars have been given importance.

a. *First Phase (1957–1974)*

Maize was the first major cereal crop in India to be affected by hybridisation. Initial efforts were made to identify yellow flint type inbreds[33] with disease and pest resistance, which could be combined in hybrids. In 1961, the first four double cross maize hybrids (Ganga 1, Ganga 101, Ranjit and Deccan) were released by the public research system for commercial cultivation. Emphasis soon shifted towards composite breeding in view of the problems associated with hybrid seed production, such as replacement of seeds. India is the first country in the world to have developed composite varieties in maize, thus helping the farmers to avoid the replacement of the seed every year (as in the case of hybrids). The release of six maize composites (Amber, Jawahar, Kisan, Vikram, Sona and Vijay) in 1967 has been another significant milestone in the history of maize research in India. Composites like Vijay, Kisan and Amber have shown wide adaptability in addition to high yield potential. These also have a marked resistance to major diseases and pests affecting maize. Most of the hybrids and composites released for cultivation have fairly high levels of resistance to foliar diseases: Ganga 5 (1968) has marked resistance to leaf blight and brown stripe downy mildew; Ganga Safed 2 (1963), Deccan (1961) and Him 123 (1964) have shown considerable resistance to leaf blight; and a number of available maize varieties and hybrids have been screened for borer resistance.[34] In the early 1970s, significant improvement in protein quality was also brought about by the use of the opaque-2 gene. This led to the release of opaque-2 composites

[33] A homozygous line developed by continuous mating of closely related (by ancestry) individuals.

[34] Figures in brackets refer to the year of release of maize cultivars; Stem borers, *Chilo partellus* and *Sesamia inferens*, are the main pests in the country in all cropping seasons.

in 1971, namely, Rattan, Shakti and Protina, which contain 100 % and 60 % lysine and tryptophan (essential amino acids), respectively than the normal maize varieties.[35]

b. *Second Phase (1974–1989)*

In the mid 1970s, research was carried out to develop more productive, disease resistant and nutritionally superior composite varieties for direct use and to serve as the basic materials for generating superior composite varieties for the hybrid programme. At the same time, special emphasis was given to develop and improve early and very early maturing varieties for rainfed cultivation and for regions where succeeding crops were to be grown. In the early 1980s, one of the components of the population improvement programme was oriented towards inbred enrichment and enhancement to develop heterotic pools for hybrid development. In this, important features were introgression of materials having multiple disease resistance, increase in frequency of desirable alleles for stalk borer resistance, and improvement in tolerance to soil-moisture stress. Some of the desired inbreds like CM 111, CM 119, CM 202, CM 208, CM 300, CM 400, etc., have been used in the development of several hybrids. Five pools, viz., AB yellows, AB white, BC yellow, CD yellow and CD white, were formulated, representing a wide array of maturity levels and grain colour (yellow and white) to develop promising varieties. VL 88, an early-maturing composite was developed from the CD yellow pool and gained wide popularity among farmers.

In 1975, realising the potential of winter (*rabi*) maize, a separate winter maize-breeding programme was initiated. The development of heterotic pools exclusively for winter maize was initiated in 1980. Systematic work on *rabi* maize was taken up in the south in the mid 1970s and in the north in the early 1980s. With the availability of high yielding maize hybrids, it was demonstrated that maize could be grown during the winter season.[36] Breeding work on fodder maize started in the 1970s, resulting in the release of the popular fodder composite African Tall in 1980.

c. *Third Phase (1990 onwards)*

Work on sweet corn and popcorns, initiated in late sixties, resulted in composites like Madhuri sweet corn (released in 1990), Amber Pop (1971) and VL Amber Pop (1983). Earlier bad effects of opaque 2 versions of maize were modified to hard opaque 2 composite and were released in 1997, in the name of Shakti1. Some of the QPM hybrids of CIMMYT, Mexico germplasm were tested and the experimental hybrids possessed high yield potential and were superior in protein quality. In 2001, India released two QPM white hybrids Shaktiman-1 (CML142 x CML150) x CML186 and Shaktiman-2 (CML176 x CML186). Directorate of Maize Research released two new yellow QPM hybrids HQ-1 and HQ-2 in 2003 using CML 161 and CML 193. For purposes of baby corn, 27 varieties and 10 hybrids of maize have been recommended by DMR. These cultivars can be grown in kharif and rabi season across the country. Baby corn is the ear of maize plant harvested young, especially when the silks have either not emerged or just emerged, and no fertilisation has taken place, depending on the cultivar grown. The dehusked young ears of baby corn are eaten as a vegetable.

[35] But they never became popular among the farmers due to poor yield, lustreless soft opaque grains, and more proneness to diseases and pests, including stored grain pests.

[36] *Rabi* maize, however, was already a popular crop in the States of Bihar, Karnataka, Tamil Nadu and Andhra Pradesh.

Table 2.33 shows the total number of hybrids and varieties developed by public-funded research institutions over the period 1961 to 2004. It is clear that till the 1980s development of varieties was given more importance, while during the 1990s, the importance shifted to hybrids.

Table 2.33: Maize Varieties and Hybrids Released by Public Research Systems in India

Period	Hybrid	Variety
First Phase (1961-74)	13	17
Second Phase (1975-89)	12	40
Third Phase (1990-04)	55	12
Total	**80**	**69**

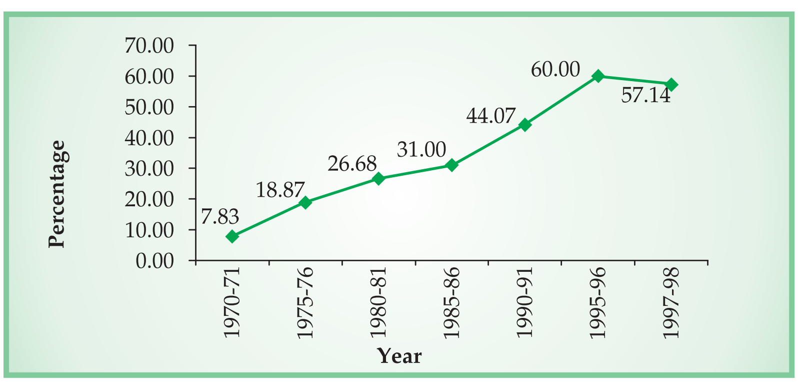
Source: DMR (2005)

Private companies were involved in the production and distribution of maize seed even during the 1970s and 1980s. With the policy reforms introduced during the late 1980s, such participation increased. During the early 1990s, the number of private maize seed companies operating in India rose sharply, and private sector investment in maize research increased significantly (Singh et al. 1995, cited in Singh et al. 1997). While the private sector has played a substantial role in maize seed production since the 1980s, their approach to breeding is qualitatively different from that of the public institutions. To quote extensively from R. P. Singh: "An analysis of nearly 100 open-pollinating varieties (OPVs) and hybrids released in India from 1961 to 1999 reveals that the products developed by public and private breeding programmes have differed. Private companies have concentrated almost exclusively on developing hybrids, which perform best in the favourable environments where most commercial maize production takes place. Public breeding programmes have produced a somewhat wider range of materials, including a number of OPVs developed specifically for marginal environments where maize production potential is low." (Singh et al. 1995) The private sector appears to have cashed in on the huge investments made by the government with regard to maize research, extension and development services. More importantly, private companies have used large amounts of ICAR and CIMMYT germplasm in their breeding programmes (Singh et al. 1995).

2.3.3.2 Measures of Impact of Technological Interventions in Maize Production

The level of adoption of high yielding varieties in maize has been increasing very gradually and was around 60 % by the late 1990s. Maize is grown essentially in unirrigated area and just about one-fifth of total maize area, even by the late 1990s, had assured irrigation (**Figure 2.16**).

Figure 2.16 Percentage Area under HYVs and Hybrid Maize



Source: www.indiastat.com; Ministry of Agriculture (various years)

Analysing the growth in area cultivated with maize in the country as a whole since 1950–51, it is clear that the expansion in area has taken place only in the 1950s and 1960s, along with a general expansion of gross cropped area. Since the 1970s, with the beginning of the Green Revolution, there has been no expansion in area under maize. It is only in the 1990s, when more hybrids were released that area under maize increased at the rate of 0.94 % per annum (**Table 2.34** and **Table 2.35**).

Table 2.34: Area, Production and Yield of Maize in India

Triennium Average centred around the year	Area (million ha)	Production (million tonnes)	Yield (kg per ha)
1951-52	3.36 (100)	2.23 (100)	663 (100)
1961-62	4.52 (135)	4.33 (194)	959 (145)
1971-72	5.79 (172)	6.33 (284)	1,093 (165)
1981-82	5.89 (175)	6.80 (305)	1,155 (174)
1991-92	5.91 (176)	9.00 (404)	1,524 (230)
2001-02	6.49 (193)	11.83 (530)	1,821 (275)

Note: Figures in brackets give the index with respect to the base year 1951-52
Source: Ministry of Agriculture (various years)

Table 2.35: Rate of Growth of Area, Production and Yield of Maize

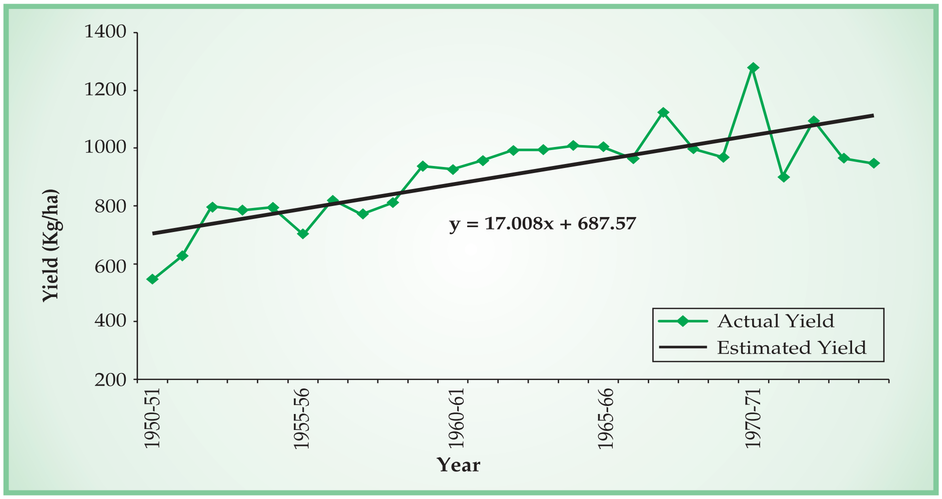
Period	Annual Compound Growth Rate of		
	Area	Production	Yield
1951-52 to 1961-62	3.01	6.86	3.76
1961-62 to 1971-72	2.51	3.87	1.32
1971-72 to 1981-82	0.17	0.72	0.55
1981-82 to1991-92	0.03	2.84	2.81
1991-92 to 2001-02	0.94	2.77	1.80
1951-52 to 2001-02	**1.33**	**3.39**	**2.04**

Source: Table 2.34

It is not clear whether the spurt in yield that initially occurred in the decade 1951–52 to 1961–62 was due to the low level of yield in the base period 1951–52 or to the double cross maize hybrids released in 1961. The growth rate of maize yield has been positive all through and has resulted in a rapid growth in maize production over the years. Production has increased nearly fivefold over the five decades from 1951–52 to 2001–02, a consequence of the development of improved varieties and hybrids.

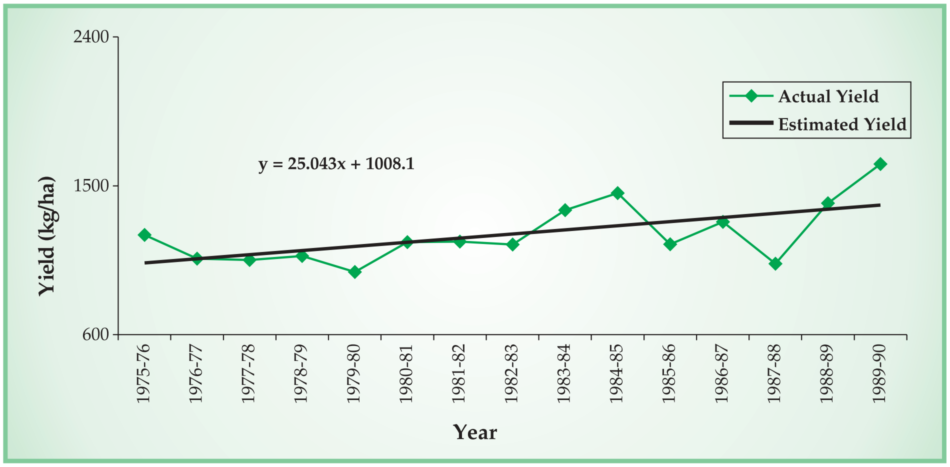
An analysis of rate of change in yield across the three phases (identified with regard to the development of the varietal improvement programme) indicates that growth rate of yield was the highest in the third phase (**Figure 2.17**, **Figure 2.18**, **Figure 2.19**). The annual increase in yield was 17 kg per hectare per annum from 1950–51 to 1974–75, 25 kg per hectare per annum during 1975–76 to 1989–90, and 33 kg per hectare per annum in the period 1990–91 to 2003–04.

Figure 2.17: Actual and Estimated Yield of Maize, 1950-51 to 1974-75



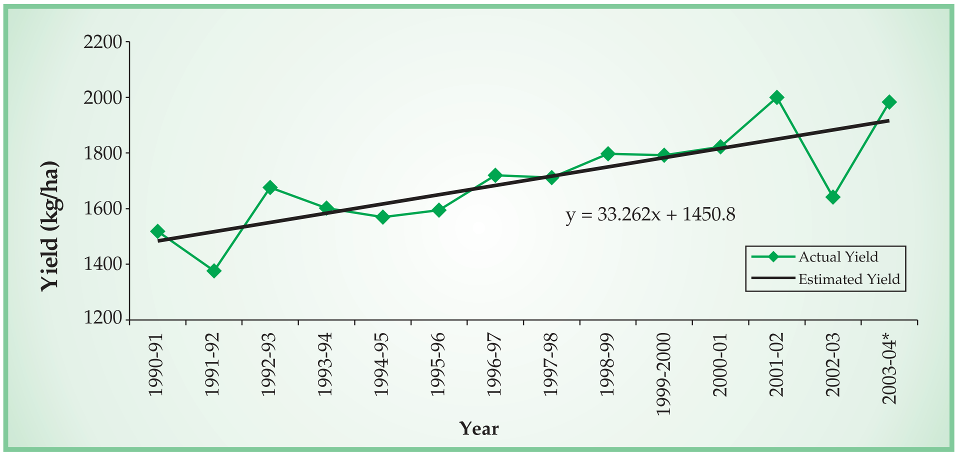
Source: Ministry of Agriculture (various years)

Figure 2.18: Actual and Estimated Yield of Maize, 1975–76 to 1989–90



Source: Ministry of Agriculture (various years)

Figure 2.19: Actual and Estimated Yield of Maize, 1990–91 to 2003–04



Source: Ministry of Agriculture (various years)

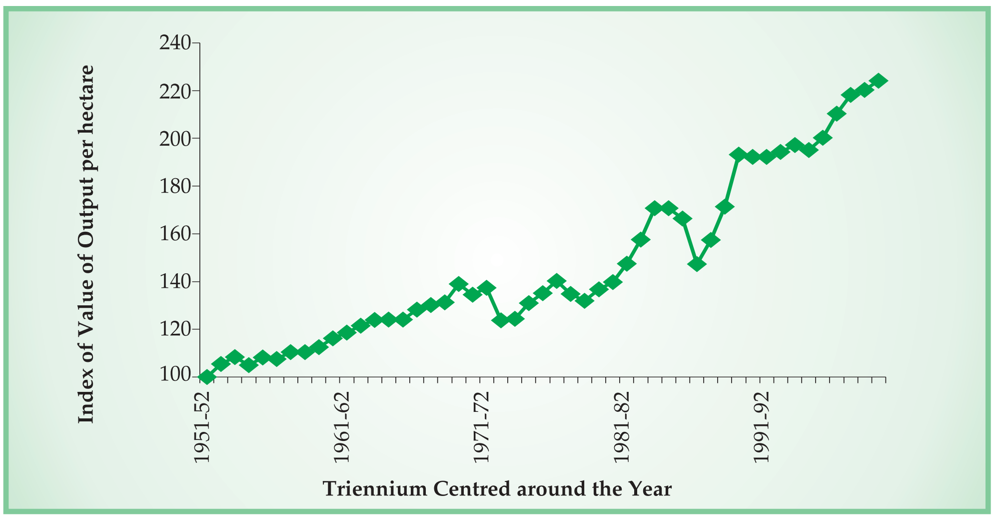
The contribution of maize to the total value of cereal output in the country has been less than 5 % over the entire period 1950–51 to 2000–01 (at 1993–94 prices). However, the value of maize output per hectare has increased from Rs.2466 in 1951–52 to Rs 5527 in 1999–2000 (at 1993-94 prices). Using the value of maize output per hectare as an indicator of technology achievement, a simple index has been calculated; the value of the index has risen from 100 in 1951–52 to 137 in 1971–72, and to 224 in 2000–01 (**Table 2.36** and **Figure 2.20**).

Table 2.36: Technology Achievement Index - Maize

Triennium centered around the year	Value of output per hectare in Rs (1993-94 prices)	Technology Achievement Index
1951-52	2,465.67	100
1961-62	2,926.27	119
1971-72	3,387.11	137
1981-82	3,634.79	147
1991-92	4,738.72	192
1999-00	5,527.11	224

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

Figure 2.20: Technology Achievement Index — Maize



Source: EPW Foundation (2004); Ministry of Agriculture (various years)

2.3.4 SORGHUM

Sorghum, popularly called jowar, is one of the most important food and fodder crops in India and occupies the third place among cereal crops (after rice and wheat) in terms of area cultivated. It is grown in two major seasons: *kharif* (June–July to September–October) and *rabi* (September–October to February–March). It is extensively cultivated in tropical and sub-tropical environments and is most suitable for rainfed farming. Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh and Gujarat are the major sorghum growing States in India.

2.3.4.1 Varietal Improvement Programme[37]

While research in sorghum had been carried out in pre-Independent India, concerted research efforts on productivity enhancement were initiated in 1962 with the establishment of the Accelerated Sorghum and Millet Improvement Project (ASMIP). ASMIP was the forerunner of the All India Coordinated Sorghum Improvement Project (AICSIP), which was established in 1969. The National Research Centre for Sorghum (NRCS) was set up in 1987 by upgrading the IARI Regional Station at Hyderabad. Organization, supervision and data analysis of AICSIP are carried out at NRCS. Short-term research collaboration with the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad, was initiated during 1990–91 and with the Australian Centre for Research in International Agriculture in 1996. In 1991, a Centre for *Rabi* Sorghum (CRS) was established at Solapur under NRCS, to strengthen the research on *rabi* sorghum (NRCS 1998). Sorghum being often cross-pollinated, it is amenable for hybrid development and therefore along with the public institutions, private sector is also involved in developing hybrids. However, given the purpose of this study, the attempt here is to analyse the improvement of sorghum cultivars in public institutions alone.[38]

Sorghum is one of the earliest crops in which hybrid breeding was initiated. As a result of rigorous research, the first hybrid, CSH 1, was released in 1964. It was an early duration dwarf hybrid released for cultivation all over India and it resulted in a quantum jump in productivity (AICSIP 1991–92). The release of hybrids CSH-1 to CSH 19R over time at the national level was an important breakthrough in Indian sorghum breeding in terms of yield enhancement and diversification of parental lines as well as progressive advances in the incorporation of resistance against major pests and diseases.

The first variety, CSV 1 (Swarna), was a direct *introduction* of line IS 3924 from the USA in 1968. By crossing temperate and tropical germplasm, subsequent varieties CSV 2 and CSV 3 were developed. CSV 4 released in 1974 became a very popular variety.

A total of 77 varieties of sorghum have been released by the efforts of plant breeders of ICAR institutions and State agricultural universities since the 1960s (**Table 2.37**).

Table 2.37: Sorghum Varieties Released by Public Research Systems in India

Period of release	Varieties suitable for			Total
	Kharif	Rabi	Kharif / Rabi	
1968-1970	1	1	-	2
1971-1980	10	2	3	15
1981-1990	22	5	-	27
1991-2000	21	7	2	30
2001	2	-	1	3
1968-2001	56	15	6	77

Source: NRCS (2005)

[37] This section is based on Bantilan et al. (2004); Rana (1996); Rao (1972); www.nrcsorghum.res.in/imp.asp

[38] It is important to bear in mind that only a partial picture has been provided here with regard to development in sorghum as the private sector that has a substantial presence in seed development has been excluded from this analysis. In the late 1990s, the contribution of the private sector to total sorghum hybrid production has been nearly 60 % (Ramakrishna and Tonapi 2005)

ICAR institutions have released 19 varieties at the national level and SAUs have been responsible for 58 varieties. More than 70 of all varieties released are suitable for the *kharif* season and the release of *rabi* varieties picked up momentum only since the 1980s. *Kharif* varieties are photosensitive, dwarf in stature and of short duration to escape infection by grain mould, while *rabi* varieties are tall and high yielding with reasonable levels of terminal drought tolerance to sustain receding residual moisture.

A total number of 31 hybrids have been released both at national and State levels (**Table 2.38**), 20 hybrids by ICAR institutions and the rest by SAUs. Among the 31 hybrids, 17 were released for the *kharif* season, 8 for *rabi*, and 6 for both *kharif* and *rabi*. The most number of hybrids has been released in the 1990s.

Table 2.38: Sorghum Hybrids Released by Public Research Systems in India

Period of release	Varieties suitable for		
	Kharif	Rabi	Kharif / Rabi
1964-1970	3	-	1
1971-1980	2	2	1
1981-1990	4	1	3
1991-2000	7	4	1
2001-2002	1	1	-
1964-2002	17	8	6

Source: NRCS (2005)

Three phases have been identified with regard to the spread of improved sorghum cultivars in India (Deb et al. 2004). The first phase, which began in 1962 and lasted until 1975, was characterised by the replacement of traditional local cultivars by improved sorghum cultivars (CSH 1). The second phase (1976–1986) was marked by the replacement of both the traditional local cultivars and the initial group of hybrids (CSH 1, CSH 2 and CSH4) with new hybrids (CSH 5 and CSH 6). The third phase started after 1986 when the second cycle hybrids were replaced by the rapid and wider adoption of a new group of sorghum cultivars comprising CSH 9, JKSH 22, CSH 13 and CSH 14.While documenting cultivar specific adoption, Deb and Bantilan found that CSH 9 was the most popular cultivar in almost all the major sorghum-growing States in 1993 (Deb and Bantilan 1998, cited in Bantilan et al. 2004).[39]

Breeding for varietal improvement also looked into the development of forage sorghum and sweet sorghum. In addition to grain sorghum, varieties exclusively for green fodder have been developed by evaluating available germplasm types and also by hybridising with wild sorghum like *S. halapanse* and *S. sudanense* to embed their drought resistance, tillering and multi-cut capabilities. Fourteen single-cut varieties, two multi-cut varieties, one single-cut hybrid and three multi-cut hybrids were released between 1976 and 2000.[40] Among these, CSH 13 (the first single-cut forage sorghum hybrid, released in 1991) and CSV 15 (a dual-purpose variety, released in 1996) have enormous yield advantage. Intensive breeding work for development of sweet sorghum varieties resulted in the release of CSV14R in 1992 and HES 4 in 1994 in Maharashtra.

[39] However, other cultivars have been accepted in some regions: For example, Mahyco 51 has been popular in Gujarat, Maharashtra, Madhya Pradesh, Tamil Nadu and Andhra Pradesh.

[40] Harvested sorghum fodder crop is classified into single-cut and multi-cut sorghum. Single-cut sorghum is suitable for minimum assured rainfall areas.

Crossing and / or back-crossing between adapted introductions and local germplasm has been used to derive improved self-pollinated varieties and parental lines. Over the 40 years from the 1960s, several Indian sorghum breeders have used numerous germplasm lines belonging to different races. Sorghum yields have increased since the 1970s and much of this gain is attributed to genetic diversity found within the species. Useful traits such as increased seed number, larger panicles, greater total plant weight, drought tolerance, disease resistance, greater leaf area indices, increased green leaf retention, and greater partitioning of dry matter have contributed to increased yields.

2.3.4.2. Measures of Impact of Technological Interventions in Sorghum Production

Figure 2.21: Percentage Area under HYVs and Hybrid Sorghum

Source: www.indiastat.com; Ministry of Agriculture (various years)

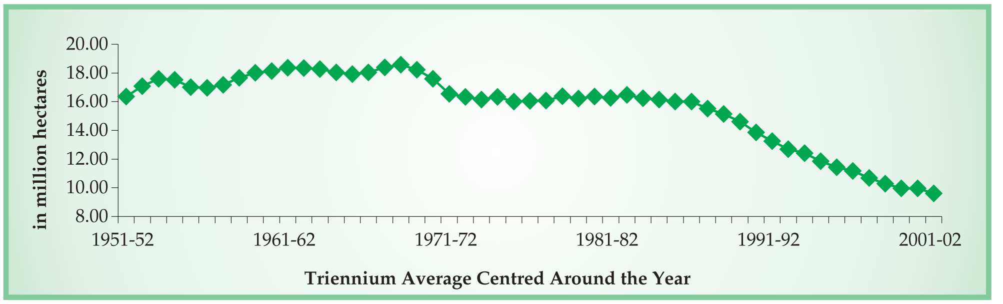
Data on the spread of improved cultivars in sorghum corroborate with the analysis and identification of the three phases proposed by Deb (**Figure 2.21**). In the first phase (1962–1975), the spread of area under HYVs was marginal, increasing gradually in the second phase and rapidly in the third phase (after 1986). Within the third phase, the 1990s have seen a spurt in percentage of area under HYVs, accounting for about 83 % in 1997–98. Sorghum is grown essentially as an unirrigated crop, with just about 8 % of area under cultivation receiving irrigation even in 2000–01. The low level of coverage under irrigation combined with high coverage under HYVs implies that the varieties and hybrids released so far are suitable for rainfed regimes.

Table 2.39: Area, Production and Yield of Sorghum in India

Triennium Average centred around the year	Area (million ha)	Production (million tonnes)	Yield (kg per ha)
1951-52	17.08	7.17	420
1961-62	18.36	9.20	501
1971-72	16.55	7.60	459
1981-82	16.26	11.08	681
1991-92	13.25	10.86	820
2001-02	9.62	7.39	768

Source: Ministry of Agriculture (various years)

Figure 2.22: Area Under Sorghum



Source: Ministry of Agriculture (various years)

Over the fifty years under consideration, area cultivated with sorghum has nearly halved. (**Table 2.39** and **Figure 2.22**). In the 1950s and 1960s, area under sorghum increased marginally, started declining slowly from the early 1970s till 1985–86 and has since declined rapidly. There have been wide fluctuations in the production of sorghum over the years, with the increasing trend up to 1990–91 followed by a decline. Sorghum production had increased from around 7 million tonnes in the early 1950s to 11 million tonnes by the early 1990s; however, it declined to the early 1950s level (i.e., 7 to 8 million tonnes) by 2001–02. The decline in production is due to decline in area, as yield has increased perceptibly because of the release of varieties and hybrids with genetic gain in yield. According to Deb, sorghum germplasm research in India has contributed to increases in genetic diversity, thereby helping to reduce instability in yield (Deb et al. 2004).

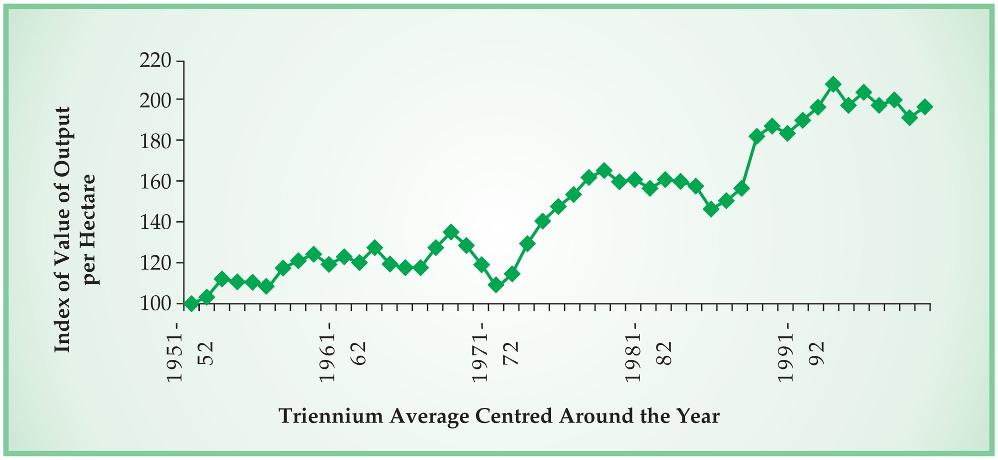
Value of jowar output (at 1993–94 prices) as a percentage of total value of cereal output was of the order of 10 % in the early 1950s and declined over the years to reach 3 % by 2000–01. The value of sorghum output per hectare, which reflects the pattern of yield when seen in constant prices, has nearly doubled over the five decades under consideration, from Rs. 1289 in 1950–51 to 1952-53 to Rs. 2542 in 1998–99 to 2000–01. The technology achievement index, computed using the value of output per hectare, has increased from a base of 100 in the early 1950s to 197 in the late 1990s. The figure clearly indicates the upward shift in the index since the mid 1980s, that is, the third phase in the development of the sorghum crop.

Table 2.40: Technology Achievement Index - Sorghum

Triennium centered around the year	Value of output per hectare in Rs. (1993-94 prices)	Technology Achievement Index
1951-52	1289.04	100
1961-62	1586.68	123
1971-72	1390.35	108
1981-82	2024.20	161
1991-92	2456.41	191
1999-2000	2542.92	197

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

Figure 2.23: Technology Achievement Index — Sorghum



Source: EPW Foundation (2004); Ministry of Agriculture (various years)

2.3.5 SUNFLOWER

Sunflower (*Helianthus annuus*) is an important oilseed crop in India, which can be grown in a variety of soils — red, sandy loams, black soils and alluvial. It is grown under assured irrigation or assured rainfall. During the 1990s, the important sunflower growing States in India were Karnataka, Maharashtra, Andhra Pradesh, Haryana, Tamil Nadu, the Punjab and Uttar Pradesh.

2.3.5.1 Varietal Improvement Programme[41]

Organised and systematic research in oilseeds is a post-independence phenomenon in India. The All India Coordinated Research Project on Oilseeds (AICORPO), a virtual landmark in the history of oilseeds research in India, was set up in April 1967. Around 1972 in the Fourth Plan period, sunflower along with safflower and niger was brought under AICORPO. Sunflower was introduced in India during 1969 when four varieties —Vniimik 8931(EC 64813), Peredovic (EC68414), Armaviski (EC 68415) and Armoverts (EC 69874) — were obtained from the former USSR. The large-scale cultivation of sunflower started in India with the introduction of these open-pollinated high yielding Russian varieties. With the inception of the All India Coordinated Research Project on Sunflower in 1972–73, the importance of heterosis breeding and the value of hybrids were recognised. Hybrid research was initiated at five centres, viz., Bangalore, Coimbatore, Digraj, Kota and Akola. In 1974–75, experimental hybrids were developed using cytoplasmic male sterile lines and restorer lines introduced from other countries. In order to raise superior populations with better adaptability and genotype environment interaction, a project for the sunflower crop was initiated in 1977. In the same year, the Directorate of Oilseed Research, an apex institute with responsibility for basic and strategic research in oilseed crops, was established in Hyderabad. In 1979, an early maturing EC 101495 was identified and released for cultivation under the name of Morden by the public research system. It gained popularity owing to desirable features such as high yield potential and high oil content. In 1980, the first hybrid, BSH 1, was released through the efforts of public research. The Government of India set up a Technology Mission on Oilseeds (TMO) in 1986 to integrate all the facets and sectors of oilseeds under a common programme. In order to give

[41] This section is based on Hegde and Dinesh Kumar (2003); Singh et al. (eds) (1997); Virupakshappa (1995)

thrust for the development of hybrids to suit diverse situations, a special project on sunflower hybrids was launched in 1989.

Over the period 1972 to 2004, a total of 18 varieties and 16 hybrids have been released by the public research system (**Table 2.41**). Five varieties that were released during 1970–80 were introductions. As a result of intensive heterosis breeding, 16 hybrids have been released since 1986 by the private sector, which entered the scene only in the 1980s, contributing to the increasing trend in the release of hybrids.

Table 2.41: Sunflower Varieties Released through Public and Private Sectors in India

Period	Public Institutions		Private R&D
	Variety	Hybrid	Hybrid
1972-80	5	1	-
1981-90	5	1	4
1991-00	7	7	5
2001-04	1	7	7
Total	**18**	**16**	**16**

Source: Damodaram and Hegde (2005)

Among the varieties / hybrids released by the public sector, two varieties, viz., EC 68414 and Morden, and three hybrids, namely, BSH 1 and KBSH 1 and KBSH 44, were recommended for cultivation in all the States and the rest of the varieties / hybrids were location specific.

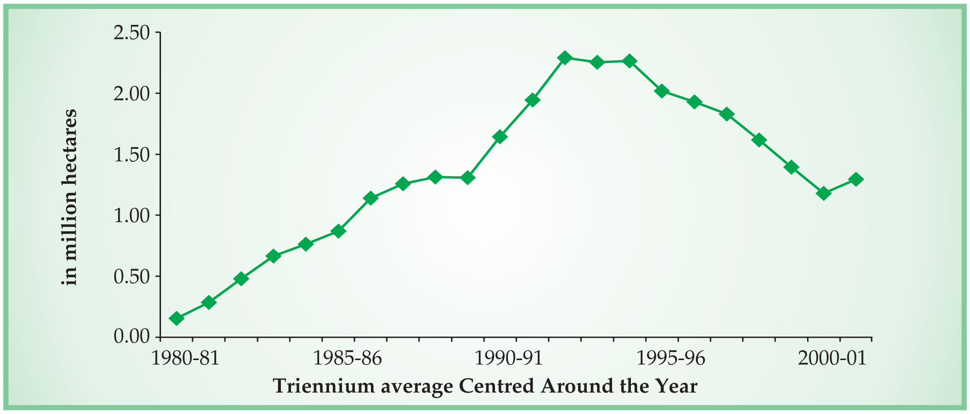
Wild sunflowers are rich sources of genetic variability in terms of resistance to biotic and abiotic factors, oil quality, etc. Research is being carried out to utilise wild sunflower species. Since the 1990s, 400 lines have been developed from 32 wild species for different characters to augment variability, a major requirement for successful breeding.

Through intensive genetic improvement, sunflower breeders have developed varieties with a shorter duration of 70–95 days and yield potential of 900 kg per hectare. Among all the hybrids released, KBSH 1 (released in 1992) recorded oil content of 43 %. One of the varieties, Siddeshwar, has tolerance to downy mildew, and five hybrids — BSH 1, PKVSH 27, and DSH 1 — have been found to be resistant / tolerant to downy mildew in addition to high yield and good oil content (Hegde and Dinesh Kumar 2003).

2.3.5.2 Measures of Impact of Technological Interventions in Sunflower Production

Given the availability of a wide spectrum of sunflower varieties in the country, area cultivated under the crop has increased significantly over the years. From about 1 lakh hectares in the early 1970s, it increased to 3 lakh hectares by the early 1980s. From **Figure 2.24**, it is clear that area under sunflower increased rapidly from the 1980s and reached 23 lakh hectares by the mid 1990s but registered a declining trend in the second half of the 1990s and was around 16 lakh hectares in 2002–03.

Figure 2.24: Area cultivated with Sunflower

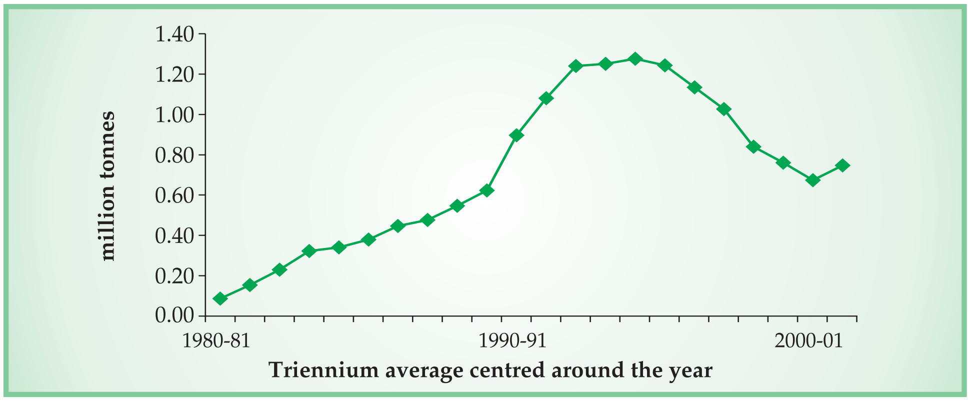


Source: Ministry of Agriculture (various years)

Sunflower has certain specific advantages that have helped in its wide adaptation:

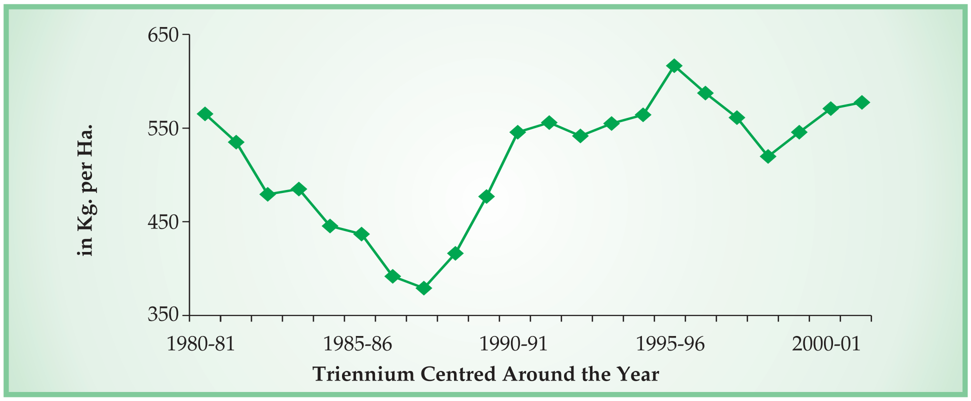
1. It is photoinsensitive and day-neutral and can be grown throughout the year, i.e., in *kharif*, *rabi*, spring / summer and in alluvial, medium black and deep black soils.
2. It can be integrated well in many of the cropping systems.
3. It can be grown as an inter-crop with pigeonpea, groundnut, soybean and green gram.

Figure 2.25: Sunflower Production



Source: Ministry of Agriculture (various years)

Figure 2.26: Per Hectare Yield of Sunflower



Source: Ministry of Agriculture (various years)

With increase in area cultivated with sunflower, its production went up from 1.5 lakh tonnes in the early 1980s to more than 10 lakh tonnes by the mid 1990s (**Figure 2.25**). Sunflower accounted for nearly 4 to 6 % of total oilseed production in the country during the 1990s. However, the extent of cultivated area as well as production of sunflower declined in the second half of the 1990s. Yield of sunflower, in the period from 1981–82 to 2001–02, has stagnated around 550 kg per hectare (**Figure 2.26**). According to Banga (2002), the advent of hybrids in sunflower has been responsible for the increase in area cultivated in the first half of the 1990s.

The significant aspect of sunflower development in the country has been in the release of suitable varieties that enabled expansion of cultivation and production of the oilseed crop over the years rather than development of varieties with high levels of yield. In other words, unlike the other crops discussed so far, the contribution of the varietal improvement programme in the case of sunflower has been with regard to development of cultivars with short duration and possibility of cultivation across the year rather than yield increase per se. Moreover, the importance of sunflower production should be seen in terms of its contribution to overall oilseed production in the country. Value of sunflower output as a percentage of total value of oilseeds in the country has increased from less than 1 % in 1980–81 to about 5 % in the mid 1990s. However, with the decline in area cultivated and production of sunflower since 1995–96, the contribution of the value of sunflower output to total value of oilseeds has also come down. Value of output per hectare of sunflower (in constant prices), that reflects yield, has remained more or less constant at about Rs. 5500 over the years 1981–82 to 1999–2000.[42]

2.3.6 SOYBEAN

Soybean is a unique legume crop that provides both protein and calories. By the late 1990s, soybean could be considered the third most important oilseed crop in the country in terms of area cultivated and production.

2.3.6.1 Varietal Improvement Programme[43]

In 1967 ICAR established the All India Coordinated Research Project on Soybean (AICRPS) to initiate R&D in soybean. This Project is being operated in 6 main centres, 11 sub centres and 11 voluntary centres. In order to intensify research in soybean, the National Research Centre for Soybean, the coordinating unit of AICRPS, was started in 1987.

In India, large-scale soybean germplasm introductions were started only in the early 1970s. For over two-and-a-half decades after Independence, area cultivated under soybean remained negligible until several promising varieties from the United States Department of Agriculture (USDA) were introduced in India in the late 1960s and ’70s.[44] Systematic genetic improvement of soybean is carried out through

[42] In this context, it is not meaningful to work out a Technology Achievement Index using the value of output per hectare as an indicator.

[43] This section is drawn from Damodaram and Hegde (2005); Hari Har Ram (1996); National Research Centre for Soybean (2005); Rai et al. (2002); Shrivastava et al. (2002); Singh et al. (2004); Tiwari et al (1999).

[44] Bragg (1969), Clark 63 (1973), Hardee (1976), Lee (1973) and Monetta (1985) are introductions from USDA. Numbers in brackets refer to the year of release.

AICRPS. Eighty-two varieties of soybean have been developed by ICAR institutes and State agricultural universities and notified for general cultivation in India. These include introductions from the United States and selection in exotic and indigenous germplasm landraces, as also hybridisation. These varieties have specific desirable characteristics such as early maturity, disease resistance, insect resistance, tolerance, pod-shattering resistance, good seed longevity, drought tolerance, suitability for food uses and high oil content.

According to Karmakar and Bhatnagar (1996), there are two groups of Indian varieties, based on their breeding history. The first group comprises varieties like Bragg, Lee, Improved Pelican, Hardee, Moneta, Shilajeeth, Co-1, Gujarat Soy 1, Gujarat Soy 2, VL Soy 2 and JS 71-05, which have been developed through direct selection from exotic and indigenous material. The second group consists of the rest of the Indian varieties developed through hybridisation and mutation in / among the varieties of the first group. A black-seeded, indigenous native variety, Kalitur, released in 1971 was popular during the mid 1970s.

Table 2.42: Number of Soybean Varieties Released in India

Period of release	Number of varieties
1970-1980	13
1981-1990	30
1991-2000	24
2001-2004	15
1970-2004	82

Source: National Research Centre for Soybean (2005)

Table 2.42 indicates that a large number of varieties were released during the 1980s and the momentum was sustained in the 1990s too. The variety Bragg, which was introduced in 1969 and subsequently released in 1971, 1973, 1975 and 1978, has played a major role in developing 14 varieties with moderate to good yield potential and tolerant / resistant to diseases. Bragg has been the only variety recommended for cultivation throughout India. Most of the varieties introduced during 1970-75 were susceptible to pests and diseases. However, resistant breeding work taken up from the 1980s onwards led to the production of varieties tolerant / resistant to major diseases and pests affecting soybean. JS 335 (released in 1994) substantially contributed to yield increase. Hara soy (released in 2001), a hybrid derivative of Himso 320 and Bragg, is immune to bacterial pustule, highly resistant to brown spot and bacterial blight, and resistant to frog eye leaf spot and pod blight. This variety has duration of 108 to 130 days and yield potential of 1500– 2000 kg / ha. It is the first culinary purpose variety released in soybean.

The varietal improvement programme takes into account specific maturity periods for given environment or agro-climatic zones. For example, in the central and southern zones, varieties with 85 to 105 days of maturity period can be grown, whereas those with 110 to 120 days of maturity period are suitable for the northern plains and hills. Varieties with specific characteristics such as pod-shattering resistance, good seed longevity, high protein / oil content, and resistant / tolerant to specific diseases have been released.

Table 2.43: Soybean Varieties Suitable for Different Agro-climatic Zones of India

S.No.	Zone	Area covered	Suitable varieties
1	Northern Hills Zone	Himachal Pradesh and the hills of Uttar Pradesh	Bragg, PK 262, PK 308, PK 327, PK 416, Pusa -16, Pusa 20, Pusa 24, Shilajeet, Shivalik VL soya 1, VL Soya 2, VL Soya 21, VL Soya 47, NRC 2
2	Northern Plains Zone	Punjab, Haryana, Delhi and the plains of Uttar Pradesh and western Bihar	Alankar, Ankur, Bragg, PK 262, PK 308, PK 327, PK 416, PK 564, PK 1024, Pusa 16, Pusa 24, Shilajeeth, SL 4
3	Central Zone	Madhya Pradesh, the Bundelkhand region of Uttar Pradesh, Rajasthan, Gujarat, northern Orissa, northern part of Maharashtra	Bragg, JS 72-44 (Gaurav), JS 72-280 (Durga), Gujarat Soybean 1, Gujarat Soybean 2, Indira Soy 9, MAUS 47, JS 75-46, JS 71-05, JS 2, JS 80-21, JS 335, JS 90-41, MACS 13, MACS 57, MACS 58, Monetta, PK 472, Pusa 16, Pusa 24, Punjab 1, NRC 2 (Ahilya 1), NRC 12 (Ahilya 2), NRC 7 (Ahilya 3), NRC 37 (Ahilya 4)
4	Southern Zone	Karnataka, Tamil Nadu, Andhra Pradesh, Kerala, Maharashtra	CO1, Hardee, KHSb 2, MACS 124, Monetta, PK 471, PK 472, PK1 029, Pusa 37, Pusa 40, MACS 450, Co2, Co (Soy) 3
5	North-eastern Zone	Assam, West Bengal, Bihar, Meghalaya, Sikkim, Arunachal Pradesh, Nagaland, Tripura	JS30-21, Birsa Soybean 1, Bragg, PK472, Pusa 16, Pusa 22, Pusa 24, MACS 124

Source: Hari Har Ram (1996); Shrivastava et al. (2002)

Table 2.44: Soybean Varieties with Specific Desirable Characteristics

Characteristic	Varieties
Pod-shattering resistance	Bragg, JS 71-05, Ahilya 3 (NRC 7), Ahilya 4 (NRC 37)
Good seed longevity	JS 80-21, Ahilya 4, Punjab 1, Ahilya 1, JS 335 and Kalitur
Suitable for mechanical harvesting	MACS 58, Ahilya 4 (NRC 37), Type 49, Durga, Punjab 1
Suitable for food uses	Hara Soya, Shilajeet, JS 2, Punjab 1, PK 472
Suitable for summer cultivation	MACS 57, Punjab 1, JS 335, Pusa 16, PI 564
Low trypsin inhibitor	Hardee, Punjab 1
Low lipoxygenase	Shilajeet, KHSb 2,Punjab1
High protein	KHSb 2, Pusa 16 and Punjab 1
Tofu quality	Punjab 1, Hardee and PK 472
High oil content (20-21%)	NRC 7

Note:

1. Many genotypes showing resistance to pod-shattering have been identified, with most released varieties being resistant. Tiwari and Raut (2004)
2. Trypsin inhibitor is the major anti-nutritional factor in raw mature soybean
3. Low lipoxygenase is responsible for the undesirable flavour of soybean products

Source: National Research Centre for Soybean (2005)

Table 2.45: Some Promising Disease Resistant/Tolerant Varieties of Soybean

Disease	Promising varieties
Anthranose*	Ahilya 2 (NRC 12), Hara Soya (Himso 1563), JS 80-21, PK 472, VL Soya 21
Charcoal rot*	Ahilya 1 (NRC 3), Ahilya 4 (NRC 37), JS 71-05, LSb 1, MACS 13
Myrothecium leaf spot**	Ahilya 3, MACS 13, MACS 124, PK 416, PS 564
Pod blight complex*	Ahilya 4 (NRC 7), Hara Soya (Himso 1563), JS 71-05, JS 80-21, Punjab 1, VL Soya 2
Rhizoctonia aerial blight	PK 416, PS 564, PK 1042, SL 295
Rust *	Ankur, Indira soya 9, JS 80-21, PK 1024, Pant Soybean 1029, Pratishta
Bacterial pustule	Ahilya 3 (NRC 7), Ahilya 4 (NRC 37), Indira Soy 9, JS 71-05, JS 90-41, Prasad (MAUS 32), PK 416, PK 1029, PI 1042, VL Soya 2
Soybean mosaic*	JS 71-05, KHSb 2, LSb 1, MACS 58, MAS 124, PK 416, PS 564, Punjab 1
Yellow mosaic *	PI 472, PS 564, PK 1024 & 1029, Pusa 37, SL 295 & 525

Note: * Moderately resistant varieties ** Tolerant varieties

Source: National Research Centre for Soybean (2005)

Table 2.46: Some Promising Pest Resistant Varieties of Soybean

Insects	Promising varieties
Defoliators	Ahilya 2 (NRC 12), Ahilya 3 (NRC 7), JS 80-21, JS 90-41, MACS 450, Monetta Parbhani Sona (MAUS 47), Pusa 16, Pusa 20, Pratap Soya (RAUS 5)
Stem fly	Ahilya 3 (NRC 7), Ahilya 4 (NRC 37), Indira Soy 9, JS 90-41, JS 93-05, MAS 124, Parbhani Sona (MAUS 47), Pooja (MAUS 2), PK 262, PK 416, PS 564, Shivalik
Girdle beetle	Ahilya 2 (NRC 12), Ahilya 3 (NRC 7), Bragg, India Soy 9, JS 93-05, Pratap Soya, PK 262, Punjab 1
Leaf miner	ADT 1, Ahilya 4 (NRC 37), Co Soya 2, Parbhani Sona (MAUS 47), Pooja (MAUS 2)
Leaf folder	ADT 1, Indira Soy 9, JS 93-05
Blue beetle	JS 93-05, Pooja (MAUS 2)
Aphids	VL Soya 47

Source: National Research Centre for Soybean (2005)

The major diseases affecting soybean include bacterial pustule, pod blight, yellow mosaic virus, rhizoctonia, aerial blight, myrothecium and bud blight. The identification of the sources of resistance for some of the diseases has helped in the development of disease- resistant varieties. Drought affects the growth and development of soybean plants and ultimately causes yield reduction. Soybean line PI 416937 has been reported to be less sensitive to drought due to its larger and thicker leaves. Indian genotypes VHC-3068, VLS-4 and Himso 107 have shown greater stability for grain yield under both stress and normal growing conditions (Sarkar et al. 1991). Similarly, varieties DS 74-42 and JS 75-19 have been good seed yielders and stable under varied environments. Soybean is grown under varying degrees of waterlogged situations in India. Varietal evaluation has shown that varieties like Kalitur, NRC-1 (yellow seed mutant of Kalitur), JS 72-280 and some other selections have better ability to withstand waterlogging. Soybean lines capable of enduring submerged conditions are being evaluated at the National Research Centre for Soybean, Indore (Bhatnagar 1994).

The International Plant Genetic Resources Institute reports that there are 1,47,000 accessions of *Glycine max* maintained by 125 institutions worldwide. In 2003, an active germplasm collection of about 3716 accessions was maintained in India at the National Research Centre for Soybean, which is a national active germplasm site (NAGS). The three major categories of soybean germplasm collection are: the base collection (at the National Gene Bank, New Delhi), the active collection (at NAGS and the regional NBPGR station at Akola), and the working collection (maintained by different AICRPS centres) (Karmakar et al. 2004).

2.3.6.2 Measures of Impact of Technological Interventions in Soybean Production

Area cultivated under soybean has been increasing rapidly since the 1970s. While just about 0.3 lakh ha were cultivated with soybean in the early 1970s, in about a decade this increased to 6 lakh hectares (**Table 2.47**). With the release of pest and disease resistant varieties during the 1980s, area under soybean further increased to 3 million hectares. Release of varieties suitable for different agro-climatic zones and special varieties for culinary purposes led to a further spread of soybean area and by 2001–02, 6 million hectares were cultivated with soybean.[45] By the late 1990s nearly 42 % of area under oilseeds in the *kharif* season was cultivated with soybean. By the 1990s soybean became the third most important oilseed crop, next only to groundnut and rapeseed-mustard, as it is one of the most stable *kharif* crops (Chauhan and Singh 2004).

Table 2.47: Area, Production and Yield of Soybean in India

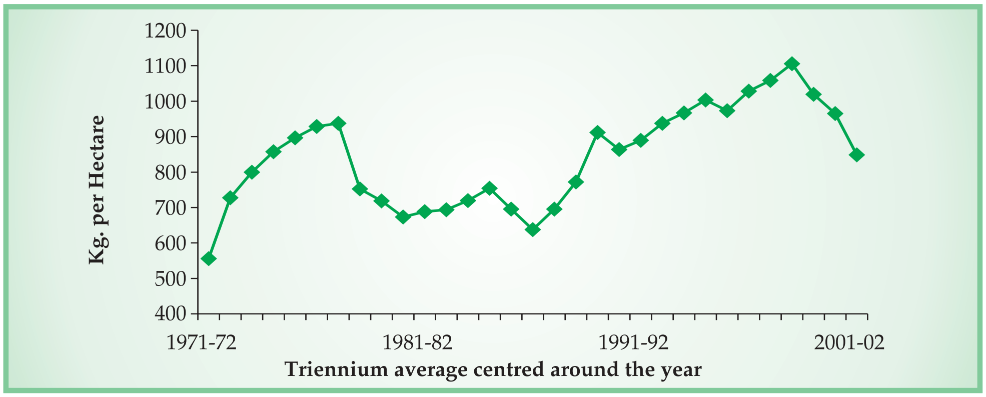
Triennium Average centred around the year	Area (million ha)	Production (million tonnes)	Yield (kg per ha)
1971-72	0.03	0.02	556
1981-82	0.62	0.43	688
1991-92	3.18	2.83	890
2001-02	6.21	5.27	848

Source: Ministry of Agriculture (various years)

With the rapid increase in area under soybean, production also increased correspondingly from 20,000 tonnes to more than 5 million tonnes over the three decades since the 1970s. Soybean is an important crop in the States of Madhya Pradesh, Maharashtra and Rajasthan. Soybean yield was 556 kg per hectare in the early 1970s and this increased to 890 kg per hectare by the early 1990s. However, soybean yield did not increase further over the decade and appeared to be fluctuating around 900 kg per hectare (**Figure 2.27**).

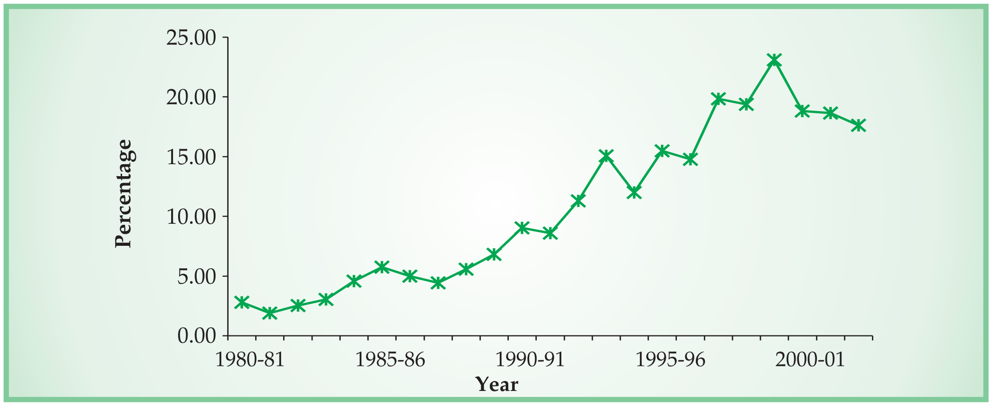
[45] On the basis of data available with Indian Vanaspati Producers Association, in www.indiastat.com

Figure 2.27: Soybean Yield



Source: Ministry of Agriculture (various years)

Figure 2.28: Value of Soybean Output as a Percentage of Total Value of All Oilseeds



Source: EPW Foundation (2004); Ministry of Agriculture (various years)

Analysing the value of soybean output as a percentage of total value of all oilseeds, the increasing importance of soybean in the oilseed sector in the country is clear. While soybean accounted for less than 5 % of total value of oilseed output in the early 1980s, this percentage increased rapidly over the years and by the late 1990s accounted for, nearly one-fifth of overall oilseed output, in value terms.[46] (**Figure 2.28**)

Value of soybean output per hectare has been increasing over the years, from less than Rs. 5000 in 1981–82 to about Rs. 8000 by the late 1990s, at 1993–94 prices (**Table 2.48** and **Figure 2.29**). The technology achievement index for soybean over 1981–82 to 1999–2000, using the value of output per hectare, has risen from 100 in 1981–82 to 161 in 1999–2000.

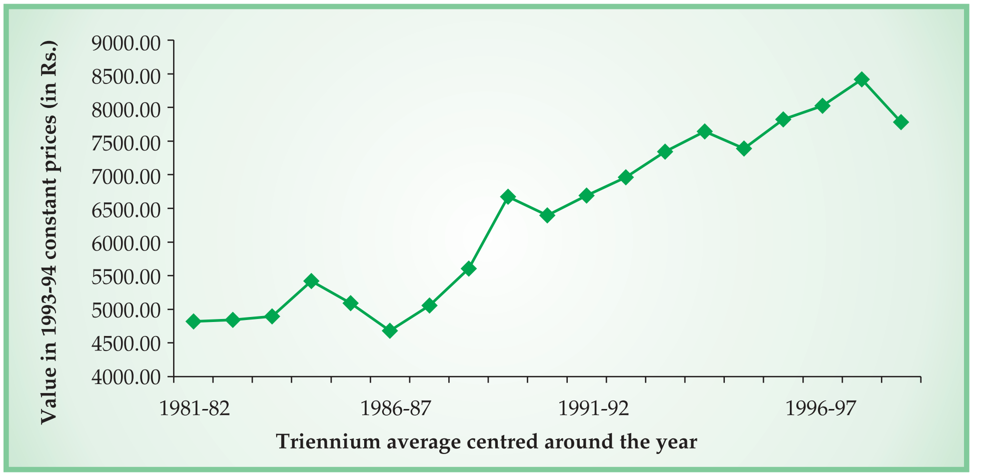
Table 2.48: Technology Achievement Index - Soybean

Triennium centered around the year	Value of output per hectare in Rs. (1993-94 prices)
1981-82	4819.99
1991-92	6691.51
1999-2000	7783.95

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

[46] Data on value of output of soybean is available only from 1980–81 onwards

Figure 2.29: Value of Output per Hectare — Soybean



Source: EPW Foundation (2004); Ministry of Agriculture (various years)

2.3.7 POTATO

Potato, valued for its high starch content, is one of the most important crops worldwide. Potato tubers also contain nutritive compounds such as protein, vitamins and minerals. In India, while the bulk of potato cultivation takes place in the Indo-Gangetic plains during short winter days from October to March, it is also grown in the hills as a rainfed *kharif* crop or as an irrigated *rabi* crop.

2.3.7.1 Varietal Improvement Programme[47]

Research in potato was started in 1935 during the colonial period with the establishment of a research station for potato breeding in the Shimla hills. In Independent India, the Central Potato Research Institute (CPRI) was established in 1949 with the mandate to undertake basic and strategic research for developing technologies to enhance the productivity of potato.[48] CPRI has 8 Regional Research Stations located in different potato growing areas across the country. In 1971, the All India Coordinated Potato Research Project (AICPRP) was also initiated to improve potato production in the country.

Till the 1950s, breeding efforts at CPRI concentrated on crossing popular native varieties and promising exotic introductions in order to develop cultivars for cultivation in sub- tropical conditions in the plains and temperate conditions in the hills. But these efforts were not very successful because of the degeneration of breeding materials during the period of testing in the plains. Attempts were then made to overcome this problem by developing a regional pattern of breeding wherein the initial breeding material was developed and maintained at Kufri (Shimla hills) and a part of the material was sent for testing at the regional stations located in the plains.

In the years 1959 to 1965, aphid free / low aphid periods were identified in the plains of India.[49] Based on this, a method known as the seed plot technique was developed. This was a system of seed potato production where healthy seed potatoes were grown during low aphid periods, accompanied by

[47] This section is drawn from Shekhawat and Naik (1999); Upadhya (1995)

[48] CPRI was established in Patna in 1949 and shifted to Shimla in 1956.

[49] Aphids are insect vectors that spread potato virus diseases.

systematic insecticide application, roguing and removal of haulms before the aphids attained critical numbers; thus the health standards for the seed crop were maintained for a number of generations (www.seedtamilnadu.com / npotato.htm). A major breakthrough in the potato improvement programme, this technique made it possible to cultivate, evaluate, select and multiply breeding material under disease-free conditions in the plains, and also contributed to the development of decentralised potato breeding in India.

Over the period 1960 to 2005, a total of 32 high yielding potato varieties have been released for commercial cultivation by CPRI.

Table 2.49: Potato Varieties Released, India, 1960-2005

Period	Number of Varieties
1960-1970	10
1971-1980	5
1981-1990	4
1991-2000	9
2001-2005	4
Total	**32**

Source: Garg et al. (1990); Gaur et al. (1999); CPRI (2005)

Analysing the salient features of the potato varieties released, it is clear that the largest number of varieties has been developed for the north Indian plains due to the large area cultivated under potato in these regions. Varieties have also been developed for the north Indian hills and other areas, viz., Sikkim and the north Bengal hills and the south Indian hills.

Table 2.50: Potato Varieties Classified by Agro-economic Zones

Agro-eco zones	Number of suitable varieties
North-Western Plains	9
West-Central Plains	14
North-Eastern plains	11
Plateau region	6
North-Western hills	5
North-Eastern hills	5
North Bengal & Sikkim hills	3
Southern hills	6

Note: If a variety is suitable for cultivation in more than one ago-eco zone, it figures in more than one zone in this Table.

Source: Gaur (1999)

Analysing other characteristics of these varieties, it is found that out of 32 varieties, 30 have resistance to some disease or other, 2 are resistant to pests and 4 are resistant to abiotic stresses. Varieties Kufri Jyoti and Kufri Kanchan are immune to wart disease, and Kufri Sheetman is resistant to frost. Five varieties — Kufri Chandramuki, Kufri Jeevan, Kufri Lauvkar, Kufri Chipsona 1 and Kufri Chipsona 2 — are suitable for processing. Popular varieties such as Kufri Jyoti, Kufri Chipsona 1 and Kufri Chipsona 2 have shown to be superior to exotic varieties for processing (Gaur et al. 1999). Kufri Puskar, released in 2005, shows the characteristic of excellent storability under high ambient temperature.

Rapid degeneration of seed stocks is a serious problem in the sub-tropical plains of India. The popular varieties Kufri Jyoti, Kufri Bahar and Kufri Sindhuri have displayed low rates of degeneration over years of cultivation in the plains. Kufri Jyoti, a medium maturity late blight resistant variety, has very wide adaptability and can be grown under all agro-climatic conditions. Kufri Jawahar, an early maturity variety, has been observed to be most suitable for use in intensive cropping systems prevalent in the north Indian Plains (Gaur et al. 1999).

Potato is traditionally grown by planting seed tubers. True potato seed (TPS) is one of the methods devised at the Central Potato Research Institute (CPRI) to supplement the supply of quality planting material. The sexually reproduced propagule can be used as an alternative source of healthy planting material. TPS can be generated with low inputs compared to many cost-intensive alternatives. Early results of the research on TPS started by CPRI showed that potato could be successfully raised from hybrid TPS and the yields were comparable to the crop raised from certified tuber seeds of standard cultivars (Upadhya et al. 1982).[50] Since 1981 the research efforts of on TPS have been augmented by the efforts of the International Potato Center (CIP), Lima. In 1984–85, a joint venture between CPRI and CIP led to the identification of suitable parental lines and standardisation of technologies for the production of hybrid TPS in large quantities. TPS is by and large free from many diseases and is the most appropriate propagule for those areas where quality tuber seed cannot be produced due to prevailing unfavourable climate. Under the joint venture between CPRI and CIP more than 250 TPS families have been evaluated for various attributes and three TPS populations, viz., HPS-1/13, TPS-C3 and 92-PT-27, have been identified as promising and recommended for commercial cultivation of ware potato crop by Indian farmers (Gaur 1999).[51]

The Indian National Potato Programme has carried out research in collaboration with CIP on the use of TPS for potato production in more than 20 locations in India. The results have shown that the yield performance of first generation seedling tubers of most of the hybrid TPS families has been either better or comparable with the certified tuber seeds of prominent cultivars. The hybrid seed of selected TPS families is being produced in India with the standard technique of using sodium vapour lights to artificially extend the photo period for induction of flowering during short winter days / *rabi* crop season in the plains.[52]

Collection, conservation and evaluation of germplasm are important prerequisites for any crop improvement programme. CPRI is responsible for collection and conservation of potato germplasm in India. Since potato is not indigenous to India, much genetic diversity is not available in the materials available in the country. CPRI acquires exotic germplasm from different countries and international gene banks, including primitive and advanced cultivars, breeding lines and semi-cultivated and wild *solanum* species. CPRI has a collection of more than 2500 germplasm accessions (Shekhawat and Naik 1999), and it also maintains the national repository of potato germplasm collection (Pandey 2006).

[50] As cited in Upadhya, 1995

[51] Ware potato crop means quality potato crop.

[52] The organisations involved in the production of hybrid TPS include CPRI, State Departments of Agriculture in West Bengal and Tripura, and some private seed producers.

2.3.7.2 Measures of Impact of Technological Interventions in Potato Production

Area, production and yield of potato have been increasing from the 1950s onwards. (**Table 2.51**) Area cultivated with potato has increased fivefold and yield has increased two-and-a-half times, resulting in a rapid thirteenfold increase in potato production over the period 1951–52 to 2001–02. Over this period, while potato yield increased at an annual compound growth rate of 1.92 %, the growth in cultivated area was much higher at 3.28 % per annum. The development of seed plot technique in the 1960s facilitated potato breeding and cultivation extensively. The release of potato varieties for commercial cultivation, with several salient features such as adaptability to different agro-economic zones, disease resistance and yield improvement, has been responsible for a sustained increase in the area and yield of potato.

Table 2.51: Area, Production and Yield of Potato in India

Triennium Average centred around the year	Area (million ha)	Production (million tonnes)	Yield (kg. per ha.)
1951-52	0.25 (100)	1.79 (100)	7,147 (100)
1961-62	0.39 (155)	2.85 (159)	7,362 (103)
1971-72	0.49 (197)	4.70 (262)	9,520 (133)
1981-82	0.74 (297)	9.85 (550)	13,247 (185)
1991-92	1.01 (403)	15.61 (872)	15,507 (217)
2001-02	1.26 (503)	23.19 (1296)	18,454 (258)

Note: Figures in brackets provide the index with regard to the base year 1951-52
Source: Ministry of Agriculture (various years)

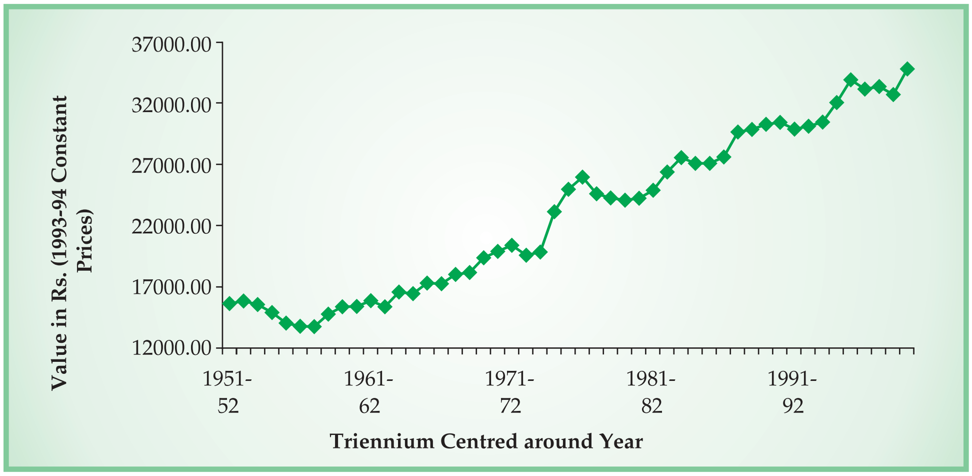
Cultivation of potatoes is concentrated along the Indo-Gangetic plains during the short winter days from October to March. Value of output per hectare of potato, at 1993–94 prices, increased from Rs. 15,624 per hectare in 1951–52 to Rs. 20,393 per hectare in 1971–72 (**Table 2.52**). Over the 1970s and '80s, the value of potato output per hectare increased rapidly, and by 1999–2000 reached Rs. 35, 000 (**Figure 2.30**). Using the value of output per hectare as the index, TAI has increased from a base of 100 in 1951–52 to 223 in 1999–2000.

Table 2.52: Technology Achievement Index - Potato

Triennium centered around the year	Value of output per hectare in Rs. (1993-94 prices)	Technology Achievement Index
1951-52	15,624.40	100
1961-62	15,869.69	102
1971-72	20,392.89	131
1981-82	24,875.57	159
1991-92	29,858.57	191
1999-2000	34,783.78	223

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

Figure 2.30: Value of Output per Hectare — Potato



Source: EPW Foundation (2004); Ministry of Agriculture (various years)

2.3.8 COTTON

India has long been recognised as the home of cotton, where it has been cultivated and utilised as textile material over many centuries. India has the unique distinction of being the only country in the world where all the four cultivated species of cotton — *Gossypium arboreum* (Bengal desi), *Gossypium herbaceum*, *Gossypium hirsutum* (American cotton) and *Gossypium barbadense* (Egyptian cotton) — are grown on a commercial scale and consumed locally as well as exported. Short, coarse cotton varieties, belonging to the species *G. arboreum*, are considered indigenous to India. Most of the popular varieties and hybrids cultivated in India belong to the *G. hirsutum* group. Till the mid 1960s, Asiatic cottons (*G.arboreum* and *G. herbaceum)* were predominant in the country, while upland cotton (*G. hirsutum*) has since become the predominant species. Cotton is grown in three distinct agro-climatic regions: The north zone (The Punjab, Haryana and Rajasthan), the central zone (Gujarat, Madhya Pradesh and Maharashtra), and the south zone (Karnataka, Andhra Pradesh and Tamil Nadu).

2.3.8.1 Varietal Improvement Programme[53]

Cotton breeding started in 1904 in colonial India, with the establishment of agricultural departments in different parts of the country. The Indian Central Cotton Committee (ICCC) was constituted in 1924. In 1966 the functions of ICCC were transferred to ICAR. Cotton growing gained momentum in Independent India with the inception of the All India Coordinated Cotton Improvement Project (AICCIP) in the year 1967. The Central Institute of Cotton Research (CICR) was established in 1976 in Nagpur as an apex body of cotton research. CICR has two Regional Stations, one at Coimbatore in Tamil Nadu and the other at Sirsa in Haryana. The Coimbatore Regional Station acts as the headquarters of AICCIP, which has 10 main research centres and 11 sub-centres located in different cotton-growing States of the country.

In India, the hybrid cotton era started in the 1970s with the release of world's first cotton hybrid H 4 by the Cotton Research Station, Surat.[54] This was the introduced genotype American Nectariless crossed

[53] This section is based on Koutu and Mandloi (2002); Narayanan (1989); Ramachandran et al. (1980); Singh and Kairun (2000); Stalker (1980); Sundaram et al. (1999).

[54] This hybrid was developed by Dr.C.T. Patel, who is called the Father of Hybrid Cotton.

with the Indian variety G.67. By virtue of its high yield potential and wide adaptability, this hybrid variety became very popular among farmers, initially in Gujarat and later on in other States such as Andhra Pradesh, Karnataka, Maharashtra and Madhya Pradesh. Two years after the release of H 4, the world's first inter-specific hybrid between *G.hirsutum* (Indian Laxmi) and *G.barbadens* (Russian SB 289E), christened Varalaxmi, was released by the Cotton Research Station, Dharwad; this gave the much-needed fillip to exploit hybrid vigour further, and two medium staple hybrids JKHy-1 from Khandwa and NHH 44 from Nanded (Maharashtra) were released.

A substantial improvement in quality took place with the release in 1974 of the *G.barbadense* variety Suvin, capable of spinning 120 counts. MCU 5, the first extra long staple upland cotton variety released in 1976, was a very good source of fibre length, strength and fineness.[55] As such, it was widely used as a donor parent for improvement of fibre properties. In 1987, CICR Coimbatore, developed and released the first extra long staple intra *hirsutum* hybrid, Savitha, which was capable of spinning up to 60 counts; this was another landmark in the history of AICCIP.[56] In addition, extra long staple inter-specific hybrids like DCH 32, DHB 105 were released, by the University of Agricultural Sciences, Dharwad, and TCHB 213 was released by the Tamil Nadu Agricultural University. *G. arboreum* varieties, AKA 5 in 1983 and AKA 7 in 2001, were released for cultivation in the predominantly rainfed tracts of Maharashtra.

Extensive work has also been done on pest and disease resistance. For example, all the varieties of genera a*rboreum* and *herbaceum* released after 1967 are resistant to fusarium wilt, and MCU 5 and Surabhi are resistant to verticillium wilt. Medium staple variety Khandwa 2, released in 1982, is jassid resistant. Sources of insect resistance are mainly found in cultivated varieties, germplasm collections, wild species and microorganisms such as *Bacillus thuringiensis* (**Box 2.2**).

[55] The length of cotton fibres is a property of commercial value as the price is generally based on this characteristic. With other factors being equal, longer cottons give better spinning performance than shorter ones. Fineness, which denotes the cross-section dimensions of the fibre, determines the spinning value of cottons. Coarse cottons generally give higher values for fibre strength than finer ones.

[56] Count: a number indicating the length per unit mass of yarn.

Box 2.2 **Bt Cotton**

Cotton is highly susceptible to insects, especially to the larvae of lepidopteron pests. Use of insecticides is of a very high order in cotton cultivation in India. Bollworm is a major pest that affects cotton. Although considerable achievement has been made in controlling bollworms, damage at the most crucial stages cannot be easily contained by routine chemical, cultural and management strategy. When *Bacillus thuringiensis* (Bt), a source of insect resistance, is used to genetically modify cotton (Bt cotton), it is said to protect the cotton crop against bollworms. Across the world, the era of transgenic cotton began in 1990 with the introduction of Bt Cry 1 A (b) and Cry 1A(c) genes into cotton plants. In USA, the Monsanto Company launched the first product 'Bollgard' in 1996. Bt cotton was the *first genetically modified crop technology* to be commercialised in India. In early 2002, Indian authorities approved the first three Bt cotton hybrids developed by the joint venture Mahyco-Monsanto Biotech. By 2005, a total of 20 hybrids had been approved for cultivation in India. All these hybrids are the outcome of private R&D activities.

Bt. Hybrids under Cultivation from 2002 to 2005

Zone	**2002**	**2003**	**2004**	**2005**
North Zone Haryana, Punjab, Rajasthan	-	-	-	6 Hybrids RCH 134, RCH 317, MRC 6304, MRC 6301, Ankur 651, Ankur 2534
Central Zone Gujarat, Madhya Pradesh, Maharashtra	3 Hybrids Mech 12 Mech 162 Mech 184	3 Hybrids Mech 12 Mech 162 Mech 184	4 Hybrids Mech 12 Mech 162 Mech 184 RCH 2	12 Hybrids Mech 12, Mech 162, Mech 184, RCH 2, RCH 118, RCH 138, RCH 144, Ankur 09, Ankur 651, MRC 6301, NCS 145 (Bunny) Bt, NCS 207 (Mallika) Bt
South Zone Andhra Pradesh, Karnataka, Tamil Nadu	3 Hybrids Mech 12 Mech 162 Mech 184	3 Hybrids Mech 12 Mech 162 Mech 184	4 Hybrids Mech 12 Mech 162 Mech 184 RCH 2	9 Hybrids Mech 162*, Mech 184*, RCH 2, RCH 20, RCH 368, MRC 6322, MRC 6918, NCS 145 (Bunny) Bt, NCS 207 (Mallika) Bt
Total number of Hybrids	3	3	4	20

* Not approved in Andhra Pradesh

Source: www.cicr.nic.in ; *The Hindu Business Line*, 25 May 2005.

Under the public sector, NHH 44 Bt cotton hybrid from University of Agricultural Sciences, Dharwad, is under large-scale trials. (*The Hindu Business Line*, May 2005). Scientists of CICR, Nagpur, have selected two popular cotton varieties — an American variety called LRI 5166 grown in Tamil Nadu, Andhra Pradesh and Maharashtra and a local variety RG 8 grown in Punjab, Haryana and Rajasthan — for transferring Bt genes Cry 1 A3, Cry 1 A5 and Cry 1F. These Bt genes were identified in India. Hence, non-hybrid varieties of Bt cotton are being developed even though they may yield less than Bt cotton hybrids. If our scientists succeed in developing new Bt varieties, then farmers need not replace their seed for five years (www.thehindubusinessline.com).

The notable cultivars developed included LRA 5166, a most adaptable, medium staple cultivar released in 1983, as well as Surabhi, MCU 12 and MCU 13 that came out in 1997, 2000 and 2004, respectively. These varieties had more stability in respect to yield adaptability and spinning properties, and were well suited to the requirements of textile mills in the country.

Since 1970, a total of 290 varieties and hybrids belonging to the species *G.hirsutum*, *G.arboreum* and *G.herbaceum* have been released for commercial cultivation during the past 35 years. In the release of cotton varieties and hybrids, public institutions dominate the scene and the private sector accounts for less than 5 % of total releases (**Table 2.53**).

Table 2.53: Cotton Varieties /Hybrids Released, India

Year	Public Institutions		Private Sector	
	Varieties	Hybrid	Varieties	Hybrid
1970-1980	52	7	1	-
1981-1990	88	16	5	-
1991-2000	56	25	-	8
2001-2005	22	8	-	2
Total	**218**	**56**	**6**	**10**

Source: CICR, Coimbatore (2006); Singh (2004)

The increase in the number of varieties released, from 52 in the 1970s to 88 during the 1980s, has been due to the flow of genetic material between agro-climatic zones through the AICCIP programme. Further, newer facilities for preservation of genetic material have also contributed. During 1991–2000, though the total number of varieties released decreased, the number of hybrids released increased. Of the 218 varieties released, nearly two-thirds belonged to the *G.hirsutum* species, about one-fifth were *G.arboreum* species and the other species, *G. barbadense* and *G. herbaceum*, accounted for the rest. Varieties released were predominantly for irrigated conditions (about two-fifths of the total number). Half of the *G.hirsutum* varieties released and all of *G.barbadense* were specifically for irrigated areas. Of the rest, nearly half the varieties were released specifically for rainfed conditions while the other half were suitable for rainfed as well as irrigated conditions.[57]

A Technology Mission for Cotton (TMC) was launched in 2000 whose main objective was to develop pest resistant varieties, to strengthen research on diploid and extra long staple group of tetraploid cotton and to develop Integrated Pest Management module.

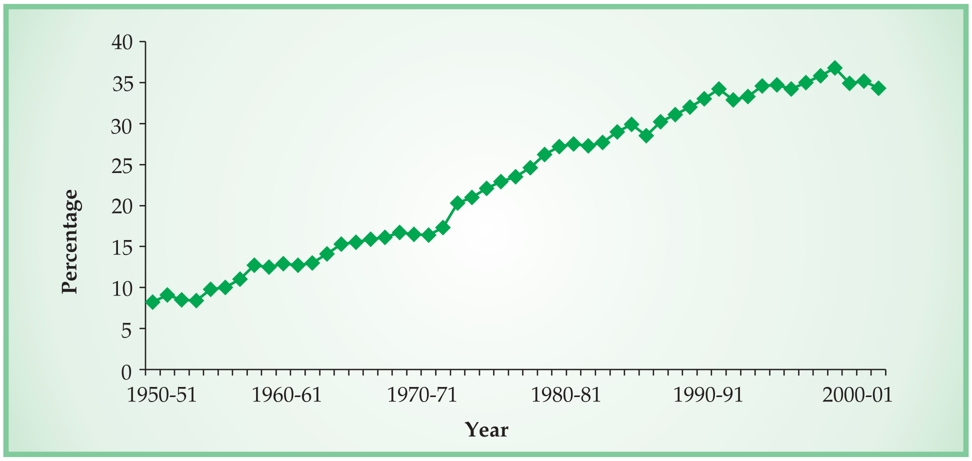
The availability of a gene pool is a must for genetic improvements of crops. The *Gossypium* germplasm is a rich conglomeration of many useful genes that can be utilised for the improvement of cotton for various needs and by-products. The national gene bank of *Gossypium* housed at CICR, Nagpur, comprises indigenous collections, accessions from other countries, and wild species. In 2004, the gene bank contained 5990 accessions of *G.hirsutum*, 1049 *G.barbadense*, 1867 *G.arboreum*, 568 *G.herbaceum*, and 173 wild species and perennials, totalling 9607 accessions (Rajendran and Jain, 2004).

[57] On the basis of data collected from the Project Coordinator, CICR, Coimbatore (2006)

2.3.8.2 Measures of Impact of Technological Interventions in Cotton

In 1950-51, 8 % of cotton area was under irrigation, increasing to 17.3 % in 1970–71. With the development of hybrids, cotton began to be cultivated increasingly as an irrigated crop. Over the 1970s, the increase was by 10 percentage points and by 1980–81, 27 % of cultivated area was under irrigation. This further increased in the 1980s and '90s and by 2001, about one-third of cotton area was under irrigation (**Figure 2.31**).

Figure 2.31: Percentage of Area under Irrigation



Source: www.indiastat.com

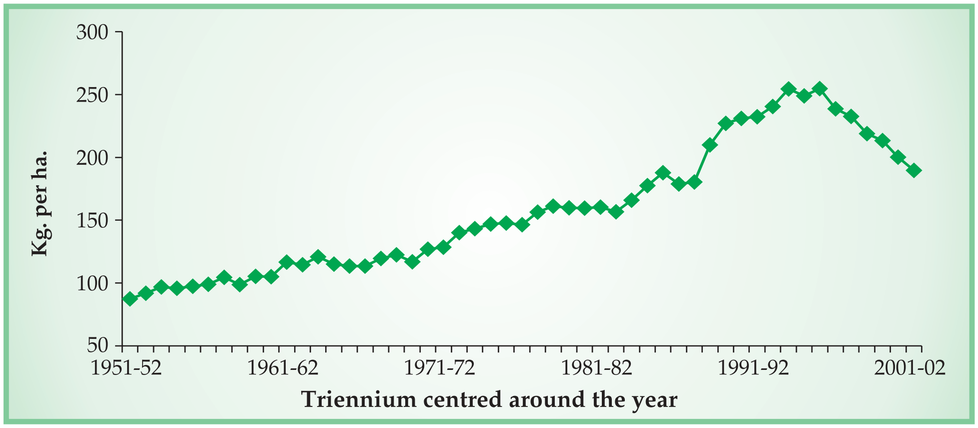
Table 2.54 Area, Production and Yield of Cotton in India

Triennium Average centred around the year	Area (million ha)	Production (million bales of 170 kg each)	Yield (kg per ha)
1951-52	6.27 (100)	3.22 (100)	87 (100)
1961-62	7.77 (124)	5.33 (166)	117 (134)
1971-72	7.70 (123)	5.82 (181)	128 (148)
1981-82	7.92 (126)	7.47 (232)	160 (184)
1991-92	7.55 (120)	10.32 (320)	232 (267)
2001-02	8.44 (135)	9.41 (292)	190 (218)

Note: Figures in brackets give the index with respect to the base year 1951-52; Production and yield of cotton refer to cotton lint.
Source: Ministry of Agriculture (various years)

From **Table 2.54** it is clear that cotton production has increased nearly threefold and that this is essentially due to the increase in cotton yield. While cotton yield increased at the rate of 1.95 % per annum over 1951–52 to 1971–72, in the next 20 years (1971–72 to 1991–92), the widespread adoption of cotton hybrids led to yield levels growing at the rate of 3.01 % per annum. However, **Figure 2.32** shows that yield levels have declined since the mid 1990s.

Figure 2.32: Cotton Yield



Source: Ministry of Agriculture (various years)

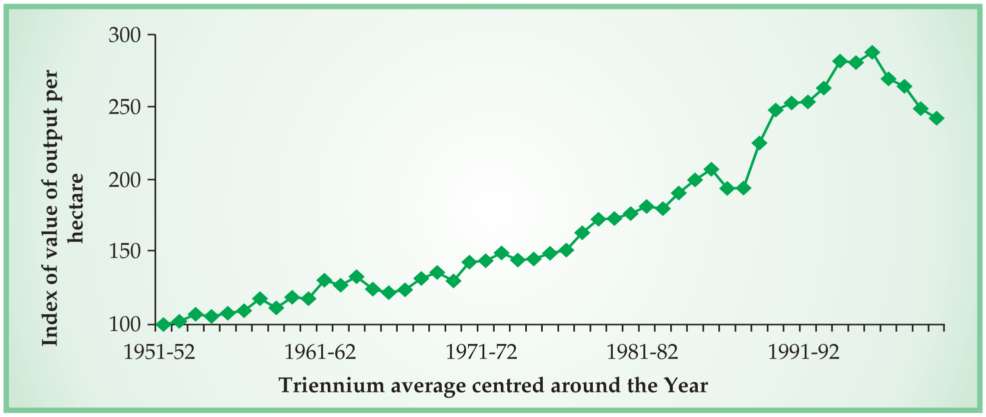
Value of output of cotton was around Rs. 4000 per hectare in the early 1950s and has grown rapidly since (**Table 2.55**). It went over Rs. 5000 per hectare by the early 1960s, rose above Rs.7000 by the early 1980s and above Rs. 10,000 by the early 1990s. By 1995–96, cotton value per hectare reached a peak of Rs.11,454 but declined thereafter. Using these figures, a technology achievement index for cotton has been worked out, the value of the index rising from a base of 100 in 1951–52 to 242 in 1999–2000 (**Figure 2.33**).

Table 2.55: Technology Achievement Index - Cotton

Triennium centered around the year	Value of output per hectare in Rs. (1993-94 prices)	Technology Achievement Index
1951-52	3,979.27	100
1961-62	5,197.36	131
1971-72	5,728.34	144
1981-82	7,219.09	181
1991-92	10,084.72	253
1999-2000	9,640.78	242

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

Figure 2.33: Technology Achievement Index — Cotton



Source: EPW Foundation (2004); Ministry of Agriculture (various years)

2.3.9 SUGARCANE

Sugarcane (*Saccharum* sp.) is an important industrial crop of India. Sugarcane growing areas may be broadly classified into two agro-climatic regions namely, sub-tropical and tropical. In the sub-tropical belt, Uttar Pradesh, Uttaranchal, Bihar, Punjab, Haryana are the important cane growing States and in the tropical belt, important sugarcane growing States are Maharashtra, Andhra Pradesh, Tamil Nadu and Gujarat. Sugarcane is cultivated throughout the country except in certain hilly tracts in Kashmir and Himachal Pradesh.

2.3.9.1 Varietal Improvement Programme[58]

The Sugarcane Breeding and Research Institute (SBRI), Coimbatore, and the Indian Institute of Sugarcane Research (IISR), Lucknow, are the major institutions playing a key role in sugarcane research in India.[59] Sugarcane research is also being carried out by several State agricultural universities and State departments of agriculture across the country. In 1969, the Sugarcane Breeding and Research Institute became part of ICAR. The Indian Institute of Sugarcane Research, Lucknow was established in 1952 by the erstwhile Central Sugarcane Committee for conducting research on fundamental and applied aspects of sugarcane culture as well as to coordinate the research work done on this crop in different States of the country. In 1969, IISR also became part of ICAR. To coordinate research activities at different research stations, an All India Coordinated Research Project (AICRP) on Sugarcane has been in operation since 1976 with its coordination unit located at IISR (www.upgov.up.nic.in).

Important milestones in sugarcane research occurred during the early part of the 20th century. *S.officinarum* clone Vellai was crossed with the locally available wild species, *S. spontaneum* at the Coimbatore facility. One of the seedlings of this inter-specific cross resulted in the first Indian sugarcane hybrid Co 205, released in 1918. In India, the noblisation[60] of *S. spontaneum* was initiated soon after the success of this first inter-specific hybrid. These early efforts culminated in the evolution of commercially important cane varieties in the 1920s and 1930s, such as Co 290, Co 312, Co 313 and Co 419 (SBRI 2002).

In the post-Independent period too, the Sugarcane Breeding and Research Institute has been the pioneer and leader in the varietal development of sugarcane. There has been a steady stream of varietal flow from SBRI to suit different agro-climatic zones. Varietal development focused on increasing the per hectare cane yield and sugar recovery, as well as on various maturity categories such as early, mid season, late, etc. Further, expanding sugarcane agriculture into new areas, through the built-in adaptability of the varieties to both biotic (red rot, smut, wilt, borers, grubs, nematodes) and abiotic stresses (extremes of temperature, soil pH, salinity, drought and waterlogging), was given importance. The seedling raising and selection programme was expanded in the mid 1970s (Lal et al. 2005). In 1975, the National Sugarcane Hybridisation Garden (NHG) was established at SBRI to provide further impetus to the varietal improvement programmes, and it shifted the emphasis to the breeding of location-specific

[58] This section is based on Balasundaram (2006); SBRI (2002; 2006); UPCSR (2005); www.fcamin.nic.in; www.sugarcane-breeding.tn.nic.in

[59] The Sugarcane Breeding and Research Institute was originally called the Sugarcane Breeding Station, established in the year 1912. In 1950, the status of the station was raised to that of an Institute and brought under the control of the Union Ministry of Food and Agriculture.

[60] Noblisation: Introgression of genes and chromosomes from noble canes (*S.officinarum*) and wild *Saccharum* species into Indian canes (*S.barberi*). This achievement was attributed to C.A.Barber and T.S.Venkataraman at the Sugarcane Breeding Station, Coimbatore.

varieties. The establishment of SAUs and the creation of all India coordinated research programmes further supported the sugarcane improvement work. By 2002, a range of varieties with a wide genetic base was available (SBRI 2002).

SBRI has generated around 2800 clones with the 'Co' prefix and has supported the breeding efforts of all the major sugarcane producing States by providing them with facilities and know-how for making crosses and selections of superior location-specific clones (Balasundaram 2006).

A total of 294 sugarcane varieties are released for cultivation in various states.

Table 2.56 Sugarcane Varieties Released, India, 1970 to 2006

Period of Release	Number of varieties
1970-1980	26
1981-1990	70
1991-2000	79
2001-2006	28
Total	**203**

Note: Details on year of release is available only for 203 varieties.
Source: AICRP on Sugarcane (2006); SBRI (2006); SRS (2006).

From the data, it may be seen that during 1970–1980, 26 varieties were released, and there has been an increase in the number of releases in the 1980s and '90s. Underlying the increase in releases has been the establishment of the National Sugarcane Hybridisation Garden that provided the required impetus to the varietal improvement programme in the country.

Table 2.57 sets out the different agro-climatic zones for sugarcane cultivation and the varieties suitable for these zones.

Table 2.57: Sugarcane Varieties Suitable for Different Agro-climatic Zones, 2005

	Area of Cultivation	Variety
1.	North-west Zone (Haryana, the Punjab, Rajasthan, Uttaranchal, western and central Uttar Pradesh	CoS 767, CoS 771, CoS 802, CoS 91230, CoS 94270, CoS 95255, CoLK 7701, CoLK 8001, CoPant 84211, CoPant 90223, CoPant 93227, CoPant 97222, Co 6304, Co 7717, CoJ 64, CoJ 75, CoH 92201
2.	North Central Zone (Bihar, West Bengal and eastern Uttar Pradesh)	BO 90, BO 91, BO 100, BO 109 (for east U.P.) BO 120, BO 128, CoSe 92423, CoSe 95422, CoSe 96234, CoSe 96436, Co 97263, Co 87268, Co 890259, CoS 767, CoS 7918 (for Bihar), CoP 9103
3.	North-east Zone (Assam)	S 101 / 72, Co 7201, CoBIn 9605
4.	Peninsular Zone (Chhattisgarh, Gujarat, Karnataka, Kerala, Maharashtra, interior Andhra Pradesh, plateau region of Tamil Nadu)	Co 1295, Co 9607, Co 7219, Co 7318, Co 7527, Co 8021 (for Gujarat), Co 8371, Co 62175, Co 85004, Co 86032, Co 87025, Co 87044, Co 91010, Co94008, CoM 7125, CoM 88121, MS 7110, MS 7455, CoC 671, CoJn 86141
5.	East Coast Zone (Orissa, coastal Andhra Pradesh and coastal Tamil Nadu)	Co 6907, Co 7219, Co 7508, Co 62175, Co 86249, CoC 671, CoC 771

Source: SBRI (2006)

Almost all the varieties released have been location specific and resistant to red rot and smut diseases. There has been a slight increase in cane yield from 1970 to 2006. The quality of sugarcane varieties has also increased over the years. Variety Co 6304 released in 1970 had a sucrose content of 11.50 % only, while sucrose content has been much higher, in the range of 15-18 %, in later varieties.

SBRI has been identified as one of the two world centres (the other being Canal Point, Florida, U.S.A) to serve as repositories for sugarcane germplasm. By early 2000s the strength of the collection is 3340 clones belonging to various categories (SBRI 2002). The major part of the sugarcane germplasm (*S.officinarum*, *S.barberi*, *S.sinense*, and *S.robustum S.edule*) is maintained at the Research Centre of SBRI in Kannur, Kerala, while wild species such as *S. spontaneum*, *Erianthus* spp., and the related genera are maintained in Coimbatore.

2.3.9.1 Measures of Impact of Technological Interventions in Sugarcane Production

The impetus received by sugarcane research since the 1970s, along with the initiation of AICRP and the release of a large number of improved varieties suitable for growth in different agro-climatic regions, has resulted in a gradual increase in area cultivated with sugarcane over the years. Area cultivated with sugarcane more than doubled in the period 1951–52 to 2001–02, from 1.79 million hectares to 4.36 million hectares (**Table 2.58**). Yield per hectare has also more than doubled, resulting in a fivefold increase in sugarcane production over this period. Expansion of area has been at an annual compound growth rate of 1.79 %, while that of yield has been at 1.51 %.

Table 2.58: Area, Production and Yield of Sugarcane in India

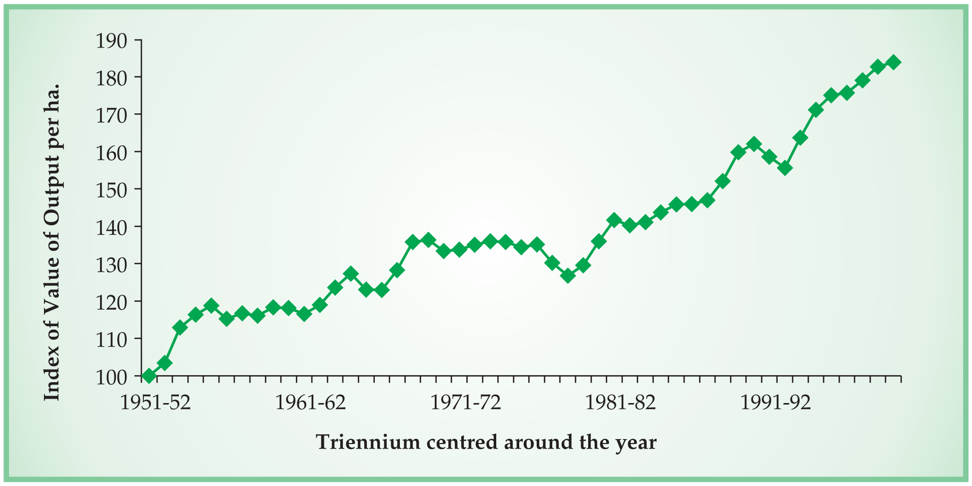
Triennium Average centred around the year	Area (million ha)	Production (million tonnes)	Yield (kg per ha)
1951-52	1.79 (100)	56.56 (100)	31,539 (100)
1961-62	2.37 (133)	101.96 (180)	42,961 (136)
1971-72	2.49 (139)	121.60 (215)	48,902 (155)
1981-82	3.07 (172)	176.71 (312)	57,497 (182)
1991-92	3.70 (207)	241.03 (426)	65,142 (207)
2001-02	4.36 (244)	291.58 (516)	66,825 (212)

Note: Figures in brackets give the index with respect to the base year 1951-52

Source: Ministry of Agriculture (various years)

Fertiliser use has been the highest for the sugarcane crop. Five year averages calculated for the years 1981–1986 have indicated consumption levels of 159 kg per hectare, increasing to 233 kg per hectare in the period 1995–2000 (Sen 2003). Value of output per hectare of sugarcane has increased from Rs. 24,467 per hectare in 1951–52 to Rs. 44,976 per hectare in 1999–2000. The technology achievement index using this indicator has increased from an index of 100 in 1951–52 to 184 in 1999–2000 (**Figure 2.34** and **Table 2.59**)

Figure 2.34: Technology Achievement Index — Sugarcane



Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

Table 2.59: Technology Achievement Index - Sugarcane

Triennium centered around the year	Value of output per hectare in Rs (1993-94 prices)	Technology Achievement Index
1951-52	24,467.13	100
1961-62	28,516.13	117
1971-72	32,727.50	134
1981-82	34,658.38	142
1991-92	38,789.13	159
1999-2000	44,976.23	184

Source: EPW Research Foundation (2004); Ministry of Agriculture (various years)

2.4. Concluding Observations

This chapter discusses significant developments in the sphere of crop production, with particular reference to the varietal improvement programmes, in post-Independent India. A detailed analytical description of the varietal improvement programme pertaining to the nine chosen crops elaborates its various dimensions. While improving crop yields is an important aspect of varietal improvement, other dimensions of the programme include improving quality, developing resistance to biotic and abiotic stresses, altering the duration of maturity, and developing photoinsensitivity. For instance, in rice, major achievements have been in developing varieties with shorter maturation, with resistance to pests and diseases and improvement in grain quality. In wheat, the significant impact of plant breeding efforts has been evidenced by a steady increase of yield levels as well as in release of late sown varieties. Improving quality has been the major aspect with regard to maize, sugarcane and oilseeds. Improving the protein content in maize, the sucrose content in sugarcane, and the oil content in soybean have been important achievements. In sorghum, apart from concentrating on grain sorghum, the programme has concentrated on developing varieties exclusively for green fodder. Moreover, the varietal improvement programme has also been concerned with altering the maturity period for a given agro-climatic zone. This has happened in the case of soybean and has resulted in a tremendous increase in area cultivated with the crop. Varieties suitable for processing, as in the case of potato, have also been an important focus.

Table 2.60 summarises the milestones achieved in the varietal improvement programme of the specified crops.

Table 2.60: Milestones in the Varietal Improvement Programme

1.	**Rice** ● Introduction of semi-dwarf rice varieties in the mid 1960s ● The first Indian dwarf variety Jaya released in 1968 ● First gall midge resistant variety Phalguna released in 1978 ● World's first high yielding dwarf variety Pusa Basmati 1 released in 1989 ● India, the second country in the world to develop its own hybrid rice (after China)
2.	**Wheat** ● Wheat variety NP 809, released in 1954, combined simultaneous resistance to all the three wheat rusts (black, brown and yellow) ● Introduction of semi-dwarf varieties Sonara 64 and Lerma Rojo in 1963 / 1964 ● Release of Sonalika in 1967, Kalyansona in 1970, and several other varieties that registered better yield
3.	**Maize** ● First crop for which ICAR initiated an All India Coordinated Crop Improvement Project (in 1957) ● First major cereal crop to be hybridised: first four double cross hybrids (Ganga 1, Ganga 101, Ranjit and Deccan) released in 1961 ● India, the first country to develop composite varieties in maize (1967) ● Release of opaque-2 composites (Quality Protein Maize), namely, Rattan, Shakti and Protina in 1971
4.	**Sorghum** ● World's second and India's first hybrid CSH 1 released in 1964
5.	**Sunflower** ● First hybrid BSH 1 released in 1982
6.	**Soybean** ● 14 varieties developed from Bragg, an introduction from US in 1969· JS 335 released in 1994 with substantial increase in yield levels over earlier varieties ● Release in 2001 of Harasoy, with immunity to bacterial pustule and resistant to other diseases
7.	**Potato** ● Development of Seed Plot Technique based on identification of aphid free / low aphid periods in the plains (1959–1965) ● Development of, and systematic work, on True Potato Seed
8.	**Cotton** ● Release of the first extra long staple variety MCU 5 in 1968. ● Release of world's first cotton hybrid H4 in 1970 and inter-specific hybrid Varalaxmi in 1972 ● Release of Suvin in 1974, a distinct landmark in the improvement of cotton quality
9.	**Sugarcane** ● Establishment of National Sugarcane Hybridisation Garden ● Co 6304 released in 1970 with high yield

The many dimensions of the varietal improvement programmes discussed above are difficult to measure and quantify. The impact of sustained efforts can however be seen in the improvement in yield per hectare, increase in crop output, and increase in the value of output per hectare. The analysis of various measurable indicators such as yield, production and value of output per hectare has clearly shown an improvement in all these aspects over the five decades since 1950 in all the nine crops studied. Using the value of output per hectare, in constant terms, an index of technology achievement over 1951–52 to 1999–2000 has been worked out for each of the crops. TAI for the entire crop husbandry sector rose from a base of 100 in 1951–52 to 256 in 1999–2000. As regards the individual crops, from a base of 100 in 1951–52, TAI for rice rose to 270, that of wheat increased to 375, maize 224, sorghum 197, potato 223, sugarcane 184 and cotton 242 by 1999–2000.[61]

While all the crops have registered an increase in yield per hectare over the years, it is important to note that there exists a gap between potential yield levels and yield levels in the farmers' fields for most of the crops. Given that potential yield levels indicate the highest yield levels that are attainable, they may be taken to reflect the research capabilities of the production system. Further, it may be possible to reduce the gap between potential and actual yield, if yield-limiting and yield-reducing factors can be identified. A yield-gap analysis for a 7-year period (1990–91 to 1997–98) shows that potential yield of paddy for the country was 5781 kg of paddy per hectare while the average yield obtained was 2759 kg of paddy per hectare. The yield-gap for paddy is of the order of 3022 kg per hectare over 1990–91 to 1997–98 (Siddiq 2000). As regards wheat, by the late 1990s there was a yield-gap of 1 to 1.5 t / ha between farmers' yield and achievable yield (Nagarajan 2006). Significant differences between potential yield and yield realised in farmers' fields have been reported with regard to all the other crops too.

The prevalence of yield-gap, however, does not take away the major achievements of our agricultural strategy in the post-Independence period: an overall rise in land productivity, a significant expansion of crop output, and an improvement in value of output per hectare. These achievements have been possible due to a conscious policy decision by the government to adopt mutually reinforcing packages of technology, services and public policies in order to promote growth. The role of the state has been extremely important in the promotion of research, dissemination of technology, creation of an atmosphere conducive for adoption of technology, provision of institutional credit on reasonable terms and investments in irrigation and rural development. However, while most of the crops registered rapid improvement in yield levels in the 1980s, the rate of growth of yield declined in the next decade. It is evident that there has been no breakthrough in technology in the 1990s even to sustain the growth levels achieved during the earlier decade. It is therefore very important that the government considerably enhances its efforts in agricultural research in order to reverse the declining trend in agricultural growth.

[61] There has been no attempt to compare the progress across crops as the objective of the study has been to understand the development with regard to individual crops.

REFERENCES

Agrawal, R.K. 1986. "Development of Improved Varieties". In J. P. Tandon and A. P. Sethi. *Twenty-five Years of Co-ordinated Wheat Research 1961-86*. New Delhi: Wheat Project Directorate.

All India Coordinated Research Project (AICRP) on Sugarcane, Lucknow. 2006. Personal Communication.

All India Coordinated Sorghum Improvement Project (AICSIP). *Annual Report 1991–-92*. Hyderabad: National Research Centre for Sorghum.

Balasundaram, N. 2006. "Sugarcane Varietal Biodiversity in India". Paper presented at the National Conference on Agro-Biodiversity organized by the National Biodiversity Authority, Chennai, at the National Institute of Ocean Technology, Chennai, February 12-15.

Banga, S.S. 2002. "Heterosis and Quality Considerations in Oilseeds". In Rai et al. (eds). *Oilseeds and Oils - Research and Development Needs*. Hyderabad: Directorate of Oilseeds Research.

Bantilan, M.C.S., U.K. Deb, C.L.L. Gowda, B.V.S. Reddy, A.B. Obilana and R.E. Evenson (eds). 2004. *Sorghum Genetic Enhancement: Research Process, Dissemination and Impacts.* Hyderabad: ICRISAT.

Bhatnagar, P.S. 1994. "Enhancement and Harnessing of Genetic Potential of Soybean Production in India". In Prasad et al. (eds.) *Sustainability in Oilseeds.*

Central Institute of Cotton Research. 2005. Personal Communication.

Central Potato Research Institute. 2005. Personal Communication.

Chauhan, G.S. and N.B. Singh. 2004. "Present Status: Soybean Production and Uses in India". In Singh et al. (eds). *Soybean Production and Improvement in India*. Indore: National Reseacrh Centre for Soybean.

Damodaram T. and D.M. Hegde. 2005. *Oilseeds Situation – A Statistical Compendium*. Hyderabad: Directorate of Oilseeds Research.

Deb U.K. and M.C.S Bantilan. 1998. "Impact on Genetic Diversity and Yield Stability". In Deb and Bantilan (eds). *Spillover Impacts of Sorghum Germplasm Research.* Hyderabad: ICRISAT. Cited in Bantilan et al. 2004.

Deb U.K., M.C.S. Bantilan, C.T. Hash and J. Ndjeunga 2004. "Adoption of Improved Sorghum Cultivars." In Bantilan et al. *Sorghum Genetic Enhancement: Research Process, Dissemination and Impacts.*

Directorate of Maize Research (DMR). 2001. *Production Technology of Quality Protein Maize.* New Delhi.

———. 2004. *Crop Profile on Maize (Package of Practices for Cultivation of Kharif & Rabi Maize).* New Delhi.

Directorate of Rice Research (DRR). 2005. Personal Communication.

Directorate of Wheat Research (DWR). 2005. Personal Communication.

Economic and Political Weekly (EPW) Research Foundation. 2004. *National Accounts Statistics of India 1950–51 to 2002–03.* Fifth Edition. Mumbai.

Evenson E. Robert, Carl E. Pray and Mark W. Rosegrant. 1999. *Agricultural Productivity and Productivity Growth in India.* Research Report 109. Washington, DC: International Food Policy Research Institute.

Garg, S.L., D.K. Agarwal and S.R.S. Arya. 1990. *Varieties Developed /Released by ICAR Institutes (Hort Crops).* New Delhi: Indian Council of Agricultural Research.

Gaur, P.C. 1999. *Manual for True Potato Seed (TPS) Production and Utilization*. Shimla: Central Potato Research Institute.

Gaur, P.C., P.S. Nasik, S.K. Kausik and S.K. Chakrabarthi. 1999. *Indian Potato Varieties.* Technical Bulletin No.51. Shimla: Central Potato Research Institute.

Hari Har Ram. 1996. "Soybean Breeding". In Jafar Nizam (ed.) *Genetic Improvement of Oil Seed Crops.* Hyderabad: Ukaaz Publications.

Hegde, D.M and V. Dinesh Kumar. 2003. *Sunflower in India*. Hyderabad: Directorate of Oilseeds Research.

Indian Agricultural Research Institute (IARI). 1998-99 to 2004-05. *National Seed Project (Crops): Annual Reports.* New Delhi.

Indian Council of Agricultural Research (ICAR). 2006. *Handbook of Agriculture.* New Delhi.

Janiah, Aldas and Mahabub Hossain. 2004. "Partnership in Public Sector Agricultural R&D: Evidence from India". *Economic and Political Weekly*. Vol. XXXIX (50).

Kapila, Uma (ed). 2004. *Indian Economy since Independence*. New Delhi: Academic Foundation.

Karmakar, P.G. and P.S. Bhatnagar. 1996. "Genetic Improvement of Soybean Varieties Released in India from 1969 to 1993". *Euphytica* 90:95-103. Cited in Tiwari et al. 1999. *The Advent and Renaissance of Soybean: A Landmark in Indian Agriculture*. Indore: National Research Centre for Soybean.

Karmakar, P.G., C. Tara Satyavathi and S.M. Hussain. 2004. "Soybean Genetic Resources in India". In N.B.Singh et al. 2004. *Soybean Production and Improvement in India*. Indore: National Research Centre for Soybean.

Koutu, G.K. and K.C. Mandloi. 2002. "Cotton". In C.B. Singh and Dhirendra Khare (eds). *Genetic Improvement of Field Crops*. Jodhpur: Scientific Publishers.

Krishniah, K. and N. Shobha Rani. 2000. "New Avenues for Augmenting and Sustaining Rice Exports from India". *International Rice Commission Newsletter*. Issue No. 49.

Lal, Jagdish, L.S. Gangwar and S.N. Nigam. 2005. "Impact of Improved Varieties on Sugarcane Production in India: Relevant Issues and Constraints". In P.K. Joshi et al (eds). *Impact of Agricultural Research: Post-Green Revolution Evidence from India*. New Delhi: NCAP-ICRISAT.

Ministry of Agriculture. *Area, Production and Yield of Principal Crops in India*. Various years. New Delhi: Government of India.

Mohan, D., S. Nagarajan, R.V.P. Singh and Jag Shoran. 2001. "Is the National Wheat Breeding Programme Demand-driven? An Analysis". *Current Science*. 81(7).

Nagarajan, S. 1998. "Perspectives on Wheat Demand and Research Needs". In Nagarajan et al. 1998. *Wheat Research Needs Beyond 2000 AD*. New Delhi: Narosa Publishing House.

———. 2004. *Sustaining the Green Revolution in India: A Success Story of Wheat*. Bangkok: Asia-Pacific Association of Agricultural Research Institutions.

———. 2006. "Sustaining Wheat Production and Ensuring Food Availability". Paper presented at the seminar on Crop Biofortification for Alleviating Micronutrient Malnutrition organized by the Department of Biotechnology, Government of India, and MSSRF, at the M S Swaminathan Research Foundation, Chennai, February 13-14.

Nagarajan, S., G.Singh and B.S.Tyagi. 1998. *Wheat Research Needs Beyond 2000 AD*. New Delhi: Narosa Publishing House.

Narayanan, S.S. 1989. *A Catalogue of Cotton Genetic Resources in India*. Nagpur: Central Institute of Cotton Research.

National Commission on Farmers. 2005. *Serving Farmers and Saving Farming – 2006: Year of Agricultural Renewal*. New Delhi: Ministry of Agriculture, Government of India.

National Research Centre for Sorghum. (NRCS). 1998. *Vision 2020 NRCS Perspective Plan*. Hyderabad.

———. 2005. Personal Communication.

National Research Centre for Soybean. 2005. Personal Communication.

Pandey, S.K. 2006. "Conservation of Genetic Diversity in Potato: Priorities and Challenges in this New Millennium". Paper presented at the National Conference on Agro-Biodiversity organized by the National Biodiversity Authority, Chennai, at the National Institute of Ocean Technology, Chennai, February 12-15.

Patnaik,Utsa. 2005a. "Theorizing Food Security and Poverty in the Era of Economic Reforms." *Social Scientist*. 33: 7-8.

———. 2005b. "Meaning of Deflationary Policies and Trade Liberalization for the Rural Economy in India". *People's Democracy*. 29 (21): 5

Prasad, M.V.R., R. Kalpana Sastry, C.V. Raghavaiah and T. Damodaram (eds). *Sustainability in Oilseeds*. Hyderabad: Indian Society of Oilseeds Research.

Punjab Agricultural University. 2002. *Research and Development of Sugarcane in the Punjab*. Ludhiana.

Rai, Mangala. 2006. "Rice-the Cereal that Feeds Billions." *Indian Farming*: 56 (7).

Rai, Mangala., Harvir Singh and D.M. Hegde (eds). 2002. *Oilseeds and Oils: Research and Development Needs*. Hyderabad: Indian Society of Oilseeds Research.

Rajendran,T.P. and K.C.Jain. 2004. *Achievements in Cotton Research.* All India Co-ordinated Cotton Improvement Project. Coimbatore: Central Institute of Cotton Research.

Ramachandran, K., L.S. Joshi, and C.B. Menon. 1980. "The Cost of Cotton Pest Control in India." *Outlook on Agriculture*, 10: 208-09.

Ramakrishna and Tonapi. 2005. Personal Communication.

Rana, B.S. 1996. "Impact of Genetic Improvement on Sorghum Productivity in India". Paper presented at the International Conference on Genetic Improvement of Sorghum and Pearl Millet, organised by the University of Nebraska, Lincoln, and held at Lubbock, USA, September 22-27.

Rao, M V. 1978. "Wheat in India –An Overview". In *Wheat Research in India 1966-76.* New Delhi: ICAR.

Rao, N.G.P. 1972. "Sorghum Breeding in India – Recent Developments". In N.G.P. Rao and L.R. House. *Sorghum in the Seventies.* New Delhi: Oxford and IBH Publishing Co.

Rao, N.G.P, Ambika Singh, V. Sivasubramanian, K.S. Murthy, A.N. Mukhopadhyay, C.C. Abraham. 1998. *Rice Research and Production in India: Present Status and a Future Perspective*. Hyderabad: Directorate of Rice Research.

Rao, Prasada. 2004. "Role of Directorate of Rice Research in Genetic Improvement of Rice Varieties of India." In S.D.Sharma and U. Prasada Rao (eds). 2004. *Genetic Improvement of Rice Varieties of India.* New Delhi: Today & Tomorrow Printers and Publishers.

Reserve Bank of India. 2003-04. *HandBook of Statistics on the Indian Economy*. Mumbai.

Sarkar, R.K., J. P. Saini, and S.D. Dube. 1991. "Testing of Soybean Genotypes for Drought Tolerance". *Indian Journal of Agricultural Sciences.* 61 (61): 369-73.

Sen, Abhijit. 2003. "Changes in Cost Structure and Farm Business Incomes, 1981-82 to 1999-00". Paper presented at the All India Conference on Agriculture and Rural Society in Contemporary India, organised by the Government of West Bengal and held at Barddhaman. West Bengal, December 17-20.

Sharma, A.K., G.P. Singh, J. Rane and S. Nagarajan. 1998. "Alternate Selection Approaches for Targeted Cropping Sequence". In Nagarajan *et al.* 1998. *Wheat Research Needs Beyond 2000 AD.*

Shekhawat, G.S. and P.S. Naik. 1999. "Potato in India". *Technical Bulletin.* No.1 Shimla: Central Potato Research Institute.

Shobha Rani, N. and R.K. Singh. 2003. "Efforts on Aromatic Rice Improvement in India" In R.K. Singh, and U.S. Singh. *A Treatise on the Scented Rices of India.* New Delhi: Kalyani Publishers.

Shoran, Jag. 2004. "Diversification of Wheat: Meeting New Demands". www.ficci.com / media-room / speeches-presentations / 2004 / oct / wheat / workshop1 / Shoran.ppt.

———. 2005. *Directorate of Wheat Research – A Profile.* Karnal: Directorate of Wheat Research.

Shrivastava, A.N, C.B. Singh and M.K. Shrivastava. 2002. "Soybean". In Singh and Khare (eds). *Genetic Improvement of Field Crops.*

Siddiq, E.A. 1990. "Export Prospects of Indian Basmati Rices". *Indian Farming.* 40(9): 45-47.

Singh, N.B., G.S. Chauhan, A.K. Vyas and O.P. Joshi (eds). 2004. *Soybean Production and Improvement in India.* Indore: National Research Centre for Soybean.

Singh, Phundan. 2004. *Cotton Breeding.* New Delhi: Kalyani Publishers.

Singh, Phundan and M.S. Kairun. 2000. "Cotton Varieties and Hybrids." *Technical Bulletin.* No. 13. Nagpur: Central Institute of Cotton Research.

Singh, R. B. and R.S. Paroda. 1994. "Sustainability and Productivity of Rice-Wheat Systems in the Asia-Pacific Region: Research, Technology and Development Needs". Cited in Sharma et al. 1998. "Alternate Selection Approaches for Targeted Cropping Sequence".

Singh, R.B and V.P. Kulshrestha. 1996. "Wheat". In *50 years of Crop Science Research in India.* New Delhi: Indian Council of Agricultural Research.

Singh, R.P., S. Pal and M. Morris. 1995. "Maize Research, Development and Seed Production in India: Contributions of the Public and Private Sectors". Economics Working Paper 95-03. Mexico: CIMMYT. Cited in Singh and Morris. 1997. *Adoption, Management and Impact of Hybrid Maize Seed in India.*

Singh, R.P. and Michael L. Morris. 1997. *Adoption, Management and Impact of Hybrid Maize Seed in India*. Economics Working Paper No. 97-06. Mexico: CIMMYT.

Singh, R.P., P.S. Reddy and V. Kiresur (eds). 1997. *Efficient Management of Dry Land Crops in India – Oilseeds*. Hyderabad: Indian Society of Oilseeds Research.

Singh R.P., Ranjit Kumar and N.P. Singh. 2003. "Transformation of the Indian Economy: Different Perspectives" In Ranjit Kumar and N.P. Singh (eds). *Maize Production in India: Golden Grain in Transition*. New Delhi: Indian Agricultural Research Institute.

Sivasubramonian, S. 2004. *The Sources of Economic Growth in India: 1950–51 to 1999–00.* New Delhi: Oxford University Press.

Stalker, H.T. 1980. "Utilization of Wild Species for Crop Improvement". *Advances in Agronomy*, 33: 111-47.

Sugarcane Breeding and Research Institute (SBRI). 2002. *Perspective Plan, 2002–2012*. Coimbatore.

———. 2006. *Report on All India Coordinated Research Project on Sugarcane.* Coimbatore.

———. 2006. Personal Communication.

Sugarcane Research Stations (SRS), Cuddalore, Coimbatore. 2006. Personal Communication.

Sundaram, V., A.K. Basu, K.R. Krishna Iyer, S.S. Narayanan, T.P. Rajendran (eds). 1999. *Handbook of Cotton in India*. Mumbai: Indian Society For Cotton Improvement.

Swaminathan, M.S. (ed) 1993. *Wheat Revolution – A Dialogue*. Madras: Macmillan India Limited.

Tandon, J.P. and M.V. Rao. 1986. "Organisation of Wheat Research in India and its Impact". In Tandon and Sethi. *Twenty-five Years of Co-ordinated Wheat Research 1961-86*. New Delhi: Wheat Project Directorate.

Tiwari, Prakash. S., O.P. Joshi and Amar N. Sharma. 1999. *The Advent and Renaissance of Soybean: A Landmark in Indian Agriculture.* Indore: National Research Centre for Soybean.

Tiwari, S.P. and V.M. Raut. 2004. "Breeding and Crop Improvement". In Singh et al. *Soybean Production and Improvement in India.*

Upadhya, M. D., Y.K. Sharma, and K.C. Garg. 1982. "Studies on the Use of True Seed for Raising Commercial Potato Crop in Potato in Developing Countries". Cited in Upadhya. 1995. "Hybrid Research in Potato: Hybrid True Potato Seed (TPS) as Future Propagule for Potato Production in India".

Upadhya, V. 1995. "Hybrid Research in Potato: Hybrid True Potato Seed (TPS) as Future Propagule for Potato Production in India". In M. Rai and Mauria (eds). *Hybrid Research and Development*. Hyderabad: Indian Society of Seed Technology.

Uttar Pradesh Council of Sugarcane Research (UPCSR). 2005. *94 years of Sugarcane Research in UP* (*1912–2005*). 2nd Vol. Shahjahanpur.

Vaidyanathan, A. 2004."India's Agricultural Development Policy". In Kapila (ed). *Indian Economy since Independence*.

Virupakshappa, 1995. "Heterosis Breeding in Sunflower: Historical Development, Present Status and Future Perspective." In Rai and Mauria (eds). *Hybrid Research and Development*.

www.agricoop.nic.in
www.censusindia.net
www.cicr.nic.in
www.dacnet.nic.in
www.fao.org
www.fcamin.nic.in
www.hybridriceindia.org
www.indiastat.com
www.maizeindia.nic.in
www.nrcsorghum.res.in
www.seedtamilnadu.com
www.sugarcane-breeding.tn.nic.in
www.thehindubusinessline.com
www.upgov.up.nic.in

ANNEXURE

List of Varieties / Hybrids Released by the Public Research System, Pertaining to the Nine Crops

1. RICE (1965–2004)

S. No.	Name of the cultivar	Year of release
a. Varieties		
1	Giza 14	1965
2	Khonorollu (T)	1965
3	Ngoba (T)	1965
4	ADT 28	1965
5	IR 8	1966
6	Annapurna	1966
7	K 84	1967
8	Jaya	1968
9	Manoharsali	1968
10	PVR-1	1968
11	Majhera 3 (T)	1968
12	Pankaj	1969
13	Gutti Akkullu	1969
14	Kusuma	1969
15	Suma	1969
16	Jalmagna(T)	1969
17	Madhukar (T)	1969
18	Cauvery	1970
19	IR 20	1970
20	Pusa 2-21	1970
21	Ratna	1970
22	Manila Paddy	1970
23	Triveni	1970
24	Pennai (ASD 14)	1970
25	Tella Hamsa	1971
26	Mahsuri	1971
27	Kolhapur scented	1971
28	Aswathy	1971
29	Rohini	1971
30	Karjat 184	1971
31	Palghar 60	1971
32	Ratnagiri 24	1971
33	Karuna	1971
34	Ponni (Mahsuri)	1971
35	Saket 4	1971

S. No.	Name of the cultivar	Year of release
36	Mahsuri	1972
37	Archana	1972
38	Deepa	1972
39	Narsing	1972
40	Panidhan 2	1972
41	Panidhan 1	1972
42	Prahlad	1972
43	Sita	1972
44	Vishnu	1972
45	Madhu	1972
46	Bharathi	1972
47	Jyothi	1972
48	Sabari	1972
49	Annapurna	1972
50	Tuljapur 1 (T)	1972
51	Hybrid Mutant 95	1972
52	Palman 579	1972
53	ADT 32	1972
54	Karikalan	1972
55	IR 24	1972
56	Gaur 1	1973
57	Gaur 10	1973
58	Gaur 100	1973
59	T 3 (T)	1973
60	Satya	1973
61	Suhasini	1973
62	Surya	1973
63	Kalinga 1	1973
64	Kalinga 2	1973
65	Shakti	1973
66	Supriya	1973
67	CO 36	1973
68	Kakatiya	1974
69	Vikram	1974
70	Hema	1974
71	Kumar	1974
72	Rajeswari	1974

S. No.	Name of the cultivar	Year of release
73	Vaigai (CO 37)	1974
74	Akashi	1975
75	IR 22	1975
76	IR 28	1975
77	IR 579	1975
78	Intan	1975
79	Mangala	1975
80	Pragathi	1975
81	Radhangiri 185-2	1975
82	Chambal	1975
83	Gautami	1976
84	Prabhat	1976
85	Rajendra	1976
86	Surekha	1976
87	Vasistha	1976
88	Kanchan	1976
89	Kiran	1976
90	GR 2	1976
91	Pushpa	1976
92	Suvarnamodan	1976
93	Jagruthi	1976
94	Kranthi	1976
95	Pragati	1976
96	Parijat	1976
97	Suphala	1976
98	PR 103	1976
99	AU1	1976
100	Bhavani	1976
101	Rasi	1977
102	Phalguna	1977
103	Madhab	1977
104	GR 11	1977
105	GR 3	1977
106	Prakash	1977
107	Red Annapurna	1977
108	Garima	1977
109	C 7306	1977
110	CR 146-7027-224	1977
111	CR 149-3244-198	1977
112	KMJ 1-17-2	1978
113	KMJ 1-19-1	1978

S. No.	Name of the cultivar	Year of release
114	Rajendradhan 201	1978
115	Rajendradhan 202	1978
116	Himdhan	1978
117	K78-13	1978
118	Tawi	1978
119	Imp. Ambemohar	1978
120	Jalgoan 5	1978
121	Ratnagiri 711-4-1	1978
122	PR 106	1978
123	TKM 9	1978
124	Prasad	1978
125	Sasyasree	1979
126	Swarnadhan	1979
127	Kothamolagolukulu 72	1979
128	CSR 5	1979
129	Bhadra	1979
130	Ratnagiri 73-1	1979
131	SYE 75	1979
132	CO 41	1979
133	IR 34	1979
134	Anamica	1980
135	Kayamkulam 1	1980
136	Asha	1980
137	Vytilla 2	1980
138	Madhuri	1980
139	IGP 1-37 (Darana)	1980
140	Indira	1980
141	Jajati	1980
142	Keshari	1980
143	Pallavi	1980
144	Ramakrishna	1980
145	Samalei	1980
146	Sattari	1980
147	Subhadra	1980
148	Puduvaiponni 1	1980
149	Punithavathy	1980
150	BK 190	1980
151	VLK Dhan 39	1980
152	Sarjoo 52	1980
153	IR 36	1981
154	Rongdoi	1981

S. No.	Name of the cultivar	Year of release
155	Jayashri	1981
156	GR 4	1981
157	Patel 85	1981
158	Poorva	1981
159	Pheu-Oibi	1981
160	Punshi	1981
161	BK 79	1981
162	ADT 36	1981
163	MDU 1	1981
164	Paiyur 1	1981
165	Narendradhan 1	1981
166	Jaladhi 1 (T)	1981
167	Jaladhi 2 (T)	1981
168	Badava Mahsuri	1982
169	Dhanya Lakshmi	1982
170	Kotha Bayyahunda	1982
171	Kothamolagolukulu 74	1982
172	Lakshmi	1982
173	Nagavali	1982
174	Sona Mahsuri	1982
175	Sowbhagya	1982
176	Swarna	1982
177	Vijaya Mahsuri	1982
178	Pusa 33	1982
179	Himalaya 1	1982
180	Himalaya 2	1982
181	Mandya Vani	1982
182	Pavizham	1982
183	PR 4141	1982
184	Punjab Basmati 1	1982
185	CO 43	1982
186	CO 44	1982
187	IR 50	1982
188	Govind	1982
189	Narendradhan 2	1982
190	Biraj	1982
191	Khitish	1982
192	Kunti	1982
193	Lakshmi	1982
194	Munal	1982
195	Suresh	1982

S. No.	Name of the cultivar	Year of release
196	Manasarovar	1983
197	Sattari	1983
198	Savithri	1983
199	Vikas	1983
200	Janaki (T)	1983
201	Sugandha (T)	1983
202	Kalinga III	1983
203	Pratap	1983
204	Rudra	1983
205	Sarathi	1983
206	Shankar	1983
207	Utkal Prabha	1983
208	MDU 2	1983
209	Thirupathisaram 1	1983
210	Pantdhan 4	1983
211	VL Dhan 206	1983
212	Radha	1984
213	Sujatha	1984
214	Safri 17 (T)	1984
215	GR 101	1984
216	SLR 51214	1984
217	JR 75	1984
218	Ambika	1984
219	Panvel 1	1984
220	Prabhavati	1984
221	Daya	1984
222	Gauri	1984
223	Bharathidasan	1984
224	Paramakudi 1	1984
225	VL Dhan 16	1984
226	Usar 1	1984
227	Seshu	1985
228	Srinivas	1985
229	Birsadhan 201	1985
230	Birsadhan 202	1985
231	Abilash	1985
232	Avinash (Gama 318)	1985
233	Mahaveera	1985
234	Karjat 1	1985
235	Ratnagiri 1	1985
236	Ratnagiri 2	1985

S. No.	Name of the cultivar	Year of release
237	Neela	1985
238	Pathara	1985
239	Rambha	1985
240	Sarasa	1985
241	Udaya	1985
242	Manhar	1985
243	Pusa 169	1986
244	Pusa 205	1986
245	Mahendra	1986
246	Prasanna	1986
247	Pratibha	1986
248	Pushkala	1986
249	Samba Mahsuri	1986
250	Sonasali	1986
251	Vajram	1986
252	Vamshi	1986
253	Vikramarya	1986
254	GR 102	1986
255	Himalaya 741	1986
256	Karna	1986
257	Mandya Vijaya	1986
258	Bhagya	1986
259	Onam	1986
260	Rasmi	1986
261	Swarnaprabha	1986
262	ACK 5	1986
263	BAM 6 (T)	1986
264	PR 108	1986
265	PR 109	1986
266	ASD 16	1986
267	TPS 2	1986
268	White Ponni	1986
269	Pantdhan 6	1986
270	Aswani	1986
271	Narendra 80	1986
272	Jogen (T)	1986
273	Kiron	1986
274	Mandira	1986
275	Sabita (T)	1986
276	Pinakini	1987
277	Saleem	1987

S. No.	Name of the cultivar	Year of release
278	Satya	1987
279	Chilarai	1987
280	Lachit	1987
281	Kanak	1987
282	Rajasree (T)	1987
283	Sudha (T)	1987
284	HKR 120	1987
285	IET 7191	1987
286	Vytilla 3	1987
287	Indrayani	1987
288	Panvel 2	1987
289	Annada	1987
290	ADT 37	1987
291	ADT 38	1987
292	VL Dhan 163	1987
293	Narendra 118	1987
294	Amulya	1988
295	Dharitri	1988
296	Pranava	1988
297	Salivanana	1988
298	Suraksha	1988
299	Tulasi	1988
300	Chaitanya	1988
301	Hari	1988
302	Nagarjuna	1988
303	Pothana	1988
304	Tikkana	1988
305	IET 7575	1988
306	Ruchi	1988
307	Palghar 1	1988
308	Pawana	1988
309	Sindewahi 1	1988
310	SKL 47-8	1988
311	Ananga	1988
312	Bhuban	1988
313	CR 1014	1988
314	Dharithri	1988
315	FR 13A (T)	1988
316	Gayatri	1988
317	Heera	1988
318	Kalashree	1988

S. No.	Name of the cultivar	Year of release
319	Kalyani II	1988
320	Kshira	1988
321	Lalat	1988
322	Moti	1988
323	Padmini	1988
324	Panidhan	1988
325	Shrabani	1988
326	SR 26 B (T)	1988
327	T 141 (T)	1988
328	T 90 (T)	1988
329	T1242 (T)	1988
330	Tara	1988
331	Tulasi	1988
332	Vanaprabha	1988
333	Jawahar	1988
334	ADT 39	1988
335	ASD 17	1988
336	TP 4121	1988
337	Dinesh	1988
338	Aditya	1989
339	CSR 10	1989
340	Govind	1989
341	Kasturi	1989
342	Nalini	1989
343	Pusa Basmati 1	1989
344	Abhaya	1989
345	Chandana	1989
346	Divya	1989
347	Krishnaveni	1989
348	Ravi	1989
349	Vibhava	1989
350	CSR 10	1989
351	Aruna	1989
352	Kanakam	1989
353	Kartika	1989
354	Makom	1989
355	Remya	1989
356	Kundalika	1989
357	Sakoli–6	1989
358	Terna	1989

S. No.	Name of the cultivar	Year of release
359	ADT 40	1989
360	IR 64	1989
361	MDU 3	1989
362	Matangini	1989
363	Panke	1989
364	Shaktiman	1990
365	Bhogali	1990
366	Rangilee	1990
367	KPH 2	1990
368	Mukthi	1990
369	Netravathi	1990
370	Jayathi	1990
371	Matta Triveni	1990
372	Neeraja	1990
373	Radhe	1990
374	SYE -ER 1	1990
375	CST 7-1	1991
376	Haryana Basmati 1	1991
377	Heera	1991
378	VL Dhan 221	1991
379	Erramallelu	1991
380	Kavya	1991
381	Nandi	1991
382	Rudramma	1991
383	Simhapuri	1991
384	Sriranga	1991
385	Swarnamukhi	1991
386	Bahadur	1991
387	Kushal	1991
388	Lakshmi	1991
389	Maniram	1991
390	Piolee	1991
391	Ranjit	1991
392	Kamini	1991
393	Ambica	1991
394	GR 103	1991
395	GR 5	1991
396	GR 6	1991
397	Narmada	1991
398	IR 30864	1991

S. No.	Name of the cultivar	Year of release
399	Seema	1991
400	Sneha	1991
401	ASD 18	1991
402	CO 45	1991
403	MDU 4	1991
404	TRC Borodhan-1	1991
405	VL Dhan 221	1991
406	VL Dhan 97	1991
407	Ajaya	1992
408	CR 1002	1992
409	IR 64	1992
410	Lunishree	1992
411	Narendra 97	1992
412	PNR 381	1992
413	Vandana	1992
414	HKR 126	1992
415	Himalaya 799	1992
416	Naggardhan	1992
417	RP 732	1992
418	Birsadhan 103	1992
419	Birsadhan 104	1992
420	Birsagora 102	1992
421	Aiswarya	1992
422	Aathira	1992
423	Kairali	1992
424	Kanchana	1992
425	Nila	1992
426	Re Maniphou 1	1992
427	Re Maniphou 2	1992
428	NEH Megha Rice 1	1992
429	NEH Megha Rice 2	1992
430	Badami	1992
431	Bhanja	1992
432	Birupa	1992
433	Ghanteswari	1992
434	Kanchan	1992
435	Khandagiri	1992
436	Mahalaxmi	1992
437	Manika	1992
438	Mehar	1992
439	Nilagiri	1992
440	Samanta	1992
441	Santepheap	1992
442	Urbashi	1992
443	Basmati 385	1992
444	PR 110	1992
445	Pantdhan 10	1992
446	Pantdhan 11	1992
447	Narendradhan 359	1993
448	Pusa 44-33	1993
449	MTU 9993	1993
450	Orugallu	1993
451	Rajavadlu	1993
452	Sagarsamba	1993
453	Varsha	1993
454	Kapilee	1993
455	Amrut	1993
456	Hemavathi	1993
457	J.J.92 (ADT41)	1993
458	TKM 10	1993
459	TPS 3	1993
460	Jal Lahari	1993
461	Jalnidhi	1993
462	Jalpriya	1993
463	Renu	1993
464	Bhupen	1993
465	Bipasha	1993
466	Jitendra	1994
467	Purnendu	1994
468	Bhadrakali	1994
469	Prabhat	1994
470	Himalaya 2216	1994
471	RP 2421	1994
472	Chenab	1994
473	Jhelum	1994
474	Ranbir Basmati	1994
475	Akash	1994
476	IET 7564	1994
477	Mahamaya	1994
478	Karjat 2	1994

S. No.	Name of the cultivar	Year of release
479	Karjat 3	1994
480	Ratnagiri 3	1994
481	Sugandha	1994
482	Aravinder	1994
483	Basmati 386	1994
484	PR 111	1994
485	Khushboo	1994
486	Mahisugandha	1994
487	Pantdhan 12	1994
488	Mahamaya	1995
489	Pusa 834	1995
490	Vijetha	1995
491	Barahavarodhi	1995
492	Gautam	1995
493	Shakuntala	1995
494	Turant Dhan	1995
495	Vaidehi (T)	1995
496	Poornima	1995
497	Shyamala	1995
498	Kasturi	1995
499	VL Dhan 121	1995
500	Birsadhan 105	1995
501	Birsadhan 106	1995
502	Birsadhan 107	1995
503	Barah Avarodhi	1995
504	Nidhi	1996
505	Taraori Basmati	1996
506	Ranjani	1996
507	ADT 42	1996
508	ASD 19	1996
509	ASD 20	1996
510	CO 46	1996
511	PKU 2	1996
512	PMK 2	1996
513	Jalaprabha (T)	1996
514	Jamini	1996
515	Khanika	1996
516	Saraswathi	1996
517	Jawahar Rice 3-45	1997
518	Pusa 677-50-103-2-9	1997

S. No.	Name of the cultivar	Year of release
519	Triguna	1997
520	Bharani	1997
521	Indursamba	1997
522	Kesava	1997
523	Krishna Hamsa	1997
524	Penna	1997
525	Siva	1997
526	Sravani	1997
527	Srikakulam Sannalu	1997
528	Swathi	1997
529	Vasundhara	1997
530	Goa 1	1997
531	Sudhir	1998
532	Sunil	1998
533	VL Dhan 61	1998
534	Basundhara	1998
535	Jayamati	1998
536	Ketekijoha	1998
537	Luit	1998
538	Padmanth	1998
539	Pamindra	1998
540	Satyaranjan	1998
541	Gurjari	1998
542	IET 8116	1998
543	Karishma	1998
544	Krishna Anjana	1998
545	Panchami	1998
546	Pavithra	1998
547	Remanica	1998
548	Revathy	1998
549	Uma	1998
550	Bhoi	1998
551	Dhala Heera	1998
552	Gajapathi	1998
553	Kharveli	1998
554	Konark	1998
555	Lalithagiri	1998
556	Radhi	1998
557	Ramchandi	1998
558	Sebati	1998

S. No.	Name of the cultivar	Year of release
559	Sonamani	1998
560	Surendra	1998
561	Tapaswini	1998
562	Vagaddhan	1998
563	ADT 43	1998
564	TKM 11	1998
565	NarendraUsar 2	1998
566	Golak	1998
567	Neeraja	1998
568	CSR 13	1999
569	CSR 27	1999
570	Pooja	1999
571	VL Dhan 81	1999
572	HKR 46	1999
573	Akutiphou	1999
574	Leimaphou	1999
575	Indravati	1999
576	Mahanandi	1999
577	Prachi	1999
578	Udayagiri	1999
579	Pantdhan 957	1999
580	PA 103	2000
581	Vivekdhan 62	2000
582	Cotton dora Sannalu	2000
583	Deepti	2000
584	Early Samba	2000
585	Maruteru Sannalu	2000
586	Somasila	2000
587	Surya	2000
588	Vedagiri	2000
589	Dhan Laxmi	2000
590	Richharia	2000
591	Bamleshwari	2000
592	Danteshwari	2000
593	Hassan Sarai	2000
594	Palamdhan 957	2000
595	Hemavathi	2000
596	KHP 5	2000
597	PKV HMT	2000
598	Karjat 4	2000
599	Panvel 3	2000
600	Phule Mawal	2000
601	Pondaghat 1	2000
602	Eriemaphou	2000
603	Sanaphou	2000
604	Durga	2000
605	Subramanya Bharathi	2000
606	PR 113	2000
607	PR 114	2000
608	PR 115	2000
609	PR 116	2000
610	ADT 44	2000
611	CO 47	2000
612	TRY 1	2000
613	Narendra Usar 3	2000
614	Bagheerathi	2000
615	Mahananda	2000
616	PNR 519	2000
617	Sashi	2000
618	Satabdi	2000
619	Anjali	2001
620	Krishna Hamsa	2001
621	Pantdhan 16	2001
622	Pusa Sugandha 2	2001
623	Pusa Sugandha 3	2001
624	Vasumati	2001
625	Vivekdhan 82	2001
626	Yamini	2001
627	Apurva	2001
628	Bapatla Sannalu	2001
629	Godavari	2001
630	Jagtial Mahsuri	2001
631	Jagtial Sannalu	2001
632	Nandyal Sannalu	2001
633	Shanti	2001
634	Sumati	2001
635	Tholakari	2001
636	Varalu	2001
637	Kohsaar	2001
638	BR 2655-9-3-1	2001

S. No.	Name of the cultivar	Year of release
639	Mugad Sugandha	2001
640	Sharavathi	2001
641	Harsha	2001
642	Rashmi	2001
643	SKL 8	2001
644	ADT (R) 45	2001
645	TRY (R) 2	2001
646	Barani Deep	2001
647	Dhanarasi	2002
648	RH-204	2002
649	Dandi	2002
650	GR 8	2002
651	Chingam	2002
652	Dhanu	2002
653	Gauri	2002
654	Kunjukunju - Priya	2002
655	Kunjukunju - Varna	2002
656	Sweta	2002
657	Varsha	2002
658	IET 15376	2002
659	IET 16075	2002
660	Bha Lum 1	2002
661	Bha Lum 2	2002
662	Lam Pnah 1	2002
663	Shah Sarang 1	2002
664	Jagabandhu	2002
665	Vandana	2002
666	Pant Sugandh Dhan 15	2002
667	Bhudeb	2002
668	Giri	2002
669	CSR 23	2003
670	Sukardhan 1	2003
671	Sumati	2003
672	Rajendra Mahsuri 1	2003
673	Indira Sugandhit Dhan 1	2003
674	Pusa 1121	2003
675	Birsa Dhan 108	2003
676	Birsa Vikas Dhan 109	2003

S. No.	Name of the cultivar	Year of release
677	Birsa Vikas Dhan 110	2003
678	Birsamati	2003
679	PKV Makarand	2003
680	SKL 3-11-25-30-36	2003
681	PMK (R) 3	2003
682	Kali Khasa	2003
683	Swati	2003
684	Pusa Sugandh5	2004
685	Richa	2004
686	Sugandhamati	2004
687	Suruchi	2004
688	Rajendra Sweta	2004
689	Kadamba	2004
690	Bhogavati	2004
691	Linglinaphou	2004
692	Pant Sugandh Dhan 17	2004
693	NDR 2026	2004
	b. Hybrids	
1.	APHR 1	1994
2.	APHR 2	1994
3.	KRH 1	1994
4.	MGR 1	1994
5.	CNRH 3	1995
6.	CORH-1	1996
7.	DRRH 1	1997
8.	Pant Sankar Dhan 1	1997
9.	PHB-71*	1997
10.	Sahayadri	1998
11.	Narendra Sankar Dhan 2	1998
12.	ADTRH – 1	1999
13.	CORH-2	1999
14.	PA 6201*	2000
15.	KRH 2	2001
16.	Pusa RH 10	2001
17.	HRI 120*	2001
18.	Pant Sankar Dhan 3	2004

Note: * Private bred hybrid released by CVRC
Source: DRR (2005); www.dacnet.nic.in

2. WHEAT (1965–2004)

S. No.	Name of the cultivar	Year of release
1.	HYB 633	1965
2.	Lerma Roja	1965
3.	NP 404	1965
4.	NP 839	1965
5.	Bijaga Yellow	1965
6.	Bijaga Red	1965
7.	NP 818	1965
8.	NP 846	1965
9.	Sonora 64	1965
10.	NP 401	1965
11.	Ganga Sonaheri	1966
12.	K 68	1968
13.	NP 884	1969
14.	NP 852	1969
15.	Safed Lerma	1969
16.	Sharbati Sonora	1969
17.	Sonalika	1969
18.	Chhoti Lerma	1969
19.	Kalyansona	1969
20.	C 306	1969
21.	PV 18	1969
22.	Kharchia 65	1970
23.	HD 1941 (Hira)	1970
24.	UP 301	1970
25.	Pusa Lerma	1971
26.	Narbada 4	1971
27.	Lal Bahadur	1971
28.	HD 1949 (Moti)	1971
29.	Motia	1971
30.	HI 7483 (Meghdoot)	1973
31.	GW 10	1973
32.	WG 357	1973
33.	NI 747-19	1973
34.	NI 5439	1973
35.	Deshratna	1974
36.	A-9-30-1	1974
37.	D 134	1974

S. No.	Name of the cultivar	Year of release
38.	K 816	1974
39.	K 78	1974
40.	K 852	1974
41.	NI 917	1974
42.	Chambal 65	1974
43.	HD1925 (Shera)	1974
44.	Durgapura 65	1974
45.	UP 310	1974
46.	UP 319	1974
47.	J 1-7	1975
48.	RAJ 911	1975
49.	HD 1982 (Janak)	1975
50.	HD 2009 (Arjun)	1975
51.	WG 377	1975
52.	UP 215	1975
53.	HD 2135 (Nilgiri)	1975
54.	HI 385 (Mukta)	1976
55.	J 24	1976
56.	HYB 65	1976
57.	HD4502 (Malvika)	1976
58.	WL 711	1977
59.	A 28	1978
60.	GW 18	1978
61.	NI 5643	1978
62.	UP 262	1978
63.	HS 1097-17 (Girija)	1978
64.	HS 1138-6-4(Sailja)	1978
65.	HD1981 (Pratap)	1978
66.	WL 410	1978
67.	Macs 9	1978
68.	Raj 821	1978
69.	Raj 1114	1978
70.	Bithoor (KML 7046)	1978
71.	VL 401	1978
72.	VL 404	1978
73.	UP 368	1978
74.	WH 147	1978
75.	WH 157	1978

S. No.	Name of the cultivar	Year of release
76.	GW 40	1979
77.	MPO 215 (Tawa 215)	1979
78.	Narmada 195	1979
79.	NI 5749	1979
80.	HD 4530	1980
81.	JNK-4W-184 (Jairaj)	1980
82.	JU 12	1980
83.	GW 1	1980
84.	HP 1102	1980
85.	HP 1209	1980
86.	HUW 12 (Malviya 12)	1980
87.	UP 115	1980
88.	VL 421	1980
89.	HD 2177	1980
90.	HD 2204	1980
91.	IWP 72	1980
92.	KSML 3	1980
93.	CC 464	1980
94.	HD 2189	1980
95.	HW 657	1980
96.	Kshipra	1981
97.	Ajanta	1981
98.	HD 2236 (Kshipra)	1982
99.	LOK 1	1982
100.	N 59	1982
101.	Narmada 112	1982
102.	HUW 37 (Malviya37)	1982
103.	HB 208	1982
104.	HS 86	1982
105.	DWL 5023	1982
106.	MLKS 11	1982
107.	WL 1562	1982
108.	HW 517	1982
109.	UP 2003	1982
110.	Raj 1555	1983
111.	Raj 1482	1983
112.	Sagarika	1983
113.	Utkalika	1983
114.	PBW 54	1983

S. No.	Name of the cultivar	Year of release
115.	K 72	1983
116.	HI 617 (Sujata)	1984
117.	HI 784 (Swati)	1984
118.	GW 89	1984
119.	Narmada 215	1984
120.	HUW 55 (Malviya55)	1984
121.	CPAN 1676 (Rohini)	1984
122.	HD 2281	1984
123.	HD 2285 (Gobind)	1984
124.	PBW 12	1984
125.	SKAML 1	1984
126.	HD 2278 (Parvati)	1984
127.	UP 2121	1984
128.	HD 2327	1985
129.	GW 2	1985
130.	J 405	1985
131.	DWR 16 (Keerthi)	1985
132.	DWR 137 (Kiran)	1985
133.	Tawa 267	1985
134.	Vinata (8223)	1985
135.	HD 2307	1985
136.	HUW 206 (Malviya206)	1985
137.	HUW 213	1985
138.	CPAN 1796	1985
139.	DL 153-2 (Kundan)	1985
140.	GW 120	1985
141.	HD 2329	1985
142.	PBW 34	1985
143.	Raj 2184	1985
144.	WH 283	1985
145.	WH 291	1985
146.	WL 2265	1985
147.	DWR 39 (Pragati)	1985
148.	HW741	1985
149.	UP 2113	1985
150.	RW 3016	1986
151.	HUW 234	1986
152.	K 7410 (Shekhar)	1986
153.	VL 616	1986

S. No.	Name of the cultivar	Year of release
154.	Raj 1972	1986
155.	HD 2385	1987
156.	BW 11 (Purbali)	1987
157.	K 8020 (Triveni)	1987
158.	UP 1109	1987
159.	PBW 65	1987
160.	PBW 120	1987
161.	PBW 138	1987
162.	MACS 1967	1987
163.	HD 2402	1988
164.	HD 2270	1988
165.	PBW 154	1988
166.	HI 977	1988
167.	RW 346	1989
168.	HI 1077 (Mangla)	1989
169.	PBN 142 (Kailash)	1989
170.	K 8027 (Maghar)	1989
171.	HS 207	1989
172.	HS 240 (Shivalik)	1989
173.	HD 2380	1989
174.	HD 2428	1989
175.	PBW 175	1989
176.	PBW 226	1989
177.	Raj 3077	1989
178.	KRL 1-4	1990
179.	HP 1493	1990
180.	GW 496	1990
181.	GW 503	1990
182.	HDR 77	1990
183.	WH 416	1990
184.	HD 2501	1990
185.	AKW 381	1991
186.	CPAN 3004 (Sangam)	1991
187.	PDW 215	1991
188.	PBW 222	1991
189.	MACS 2496	1991
190.	HUW 318 (Malviya318)	1991
191.	PBN 51	1992
192.	HP 1633 (Sonali)	1992

S. No.	Name of the cultivar	Year of release
193.	HS 277	1992
194.	HS 295	1992
195.	HPW42 (Aradhana)	1992
196.	WH 542	1992
197.	WH 533	1993
198.	DL 784-3 (Vaishali)	1993
199.	K 88(K 8804)	1993
200.	PBW 299	1993
201.	DWR 162	1993
202.	GW 173	1994
203.	GW 190	1994
204.	DT 46 (Pusa Triticale 1)	1994
205.	AKW 1071 (Purna)	1995
206.	DL 803-3 (Kanchan)	1995
207.	HI 8381 (Malvashri)	1995
208.	Saptdhara	1995
209.	WH 896	1995
210.	HP1731 (Rajasthan Lakshmi)	1995
211.	UP 2338	1995
212.	DWR 195 (Anuradha)	1995
213.	VL 719	1995
214.	K 8962 (Indra)	1996
215.	K 9107 (Dewa)	1996
216.	Raj 3765	1996
217.	PBW 343	1996
218.	PBW 373	1996
219.	DL 788-2 (Vidisha)	1997
220.	HW 2004 (Amar)	1997
221.	JWS 17 (Swapnil)	1997
222.	MACS 2694	1997
223.	NIAW 34	1997
224.	HD 2643 (Ganga)	1997
225.	HP 1744 (Rajasthan Eshwari)	1997
226.	HP1761 (Jagdish)	1997
227.	VL 738	1997
228.	PDW 233	1997
229.	DDK 1001	1997
230.	GW 273	1998
231.	GW 1139	1998

S. No.	Name of the cultivar	Year of release
232.	HPW 89 (Surabhi)	1998
233.	Sonak	1998
234.	DWR 185	1998
235.	DWR 1006	1998
236.	K 9465 (Gomti)	1998
237.	NW 1012	1998
238.	NW 1014	1998
239.	HS 365	1998
240.	DDK 1009 (Ganga)	1998
241.	MACS 2846	1998
242.	HW 1085 (Bhawani)	1998
243.	K 9006 (Ujiyar)	1998
244.	HI 8498 (Malav)	1999
245.	HPW 147	1999
246.	HUW 468 (Malviya468)	1999
247.	HD 2687 (Shresth)	1999
248.	UP 2425	1999
249.	UP 2382	1999
250.	KRL-19	2000
251.	HD 4672 (Malva)	2000
252.	HI 1418 (Naveen)	2000
253.	HI 1454 (Abha)	2000
254.	PBW 443	2000
255.	PBW 396	2000
256.	K 9644 (Atal)	2000
257.	BW 1008 (Teesta)	2000
258.	HD 2733 (VSM)	2001
259.	K 8434	2001
260.	K 9162	2001
261.	NW 1076	2001
262.	GW 322	2002
263.	HPW 184 (Chandrika)	2002
264.	WH 711	2002
265.	VL 802	2002
266.	MPO 1106 (Sudha)	2002
267.	NIAW 301 (Trimbak)	2002

S. No.	Name of the cultivar	Year of release
268.	NIDW 15	2002
269.	DBW 14	2002
270.	HUW 533	2002
271.	HW 2045 (Kaushambi)	2002
272.	MACS 6145	2002
273.	NW 2036	2002
274.	HS 375	2002
275.	HS 420	2002
276.	VL 804	2002
277.	VL 829	2002
278.	WH 912	2002
279.	HD 2781 (Aditya)	2002
280.	HUW 510	2002
281.	Raj 3777	2002
282.	K 9533 (Naina)	2002
283.	K7903(Halna)	2002
284.	HI 1500 (Amrita)	2003
285.	MP 4010	2003
286.	NIDW 295	2003
287.	HD 2824	2003
288.	VL 832	2003
289.	PBW 502	2003
290.	PBW 509	2003
291.	TL 2908	2003
292.	Raj 4037	2003
293.	Raj 4057	003
294.	UP 2565	2003
295.	AKAW 3722	2003
296.	HD 2864 (Urja)	2004
297.	HI 8627	2004
298.	SKW 196 (Shalimar wheat-1)	2004
299.	PDW 291	2004
300.	PDW 274	2004
301.	HD 2833 (Tripti)	2004
302.	K 9351	2004
303.	NW 1067	2004

Source: DWR (2005)

3. MAIZE (1961–2004)

S. No.	Name of the cultivar	Year of release
a. Varieties		
1	A-de-Cuba	1964
2	Amber	1967
3	Jawahar	1967
4	Kisan	1967
5	Sona	1967
6	Vijay	1967
7	Vikram	1967
8	C1	1968
9	C2	1968
10	Amber Pop	1971
11	Chandan safed-2	1971
12	Protina	1971
13	Rattam	1971
14	Shakti	1971
15	Makki Safed-1	1973
16	Chandan 1	1974
17	Rajendra Makka-1	1974
18	Agaiti 76	1976
19	Chandan-3	1976
20	Moti	1977
21	Diara	1978
22	Mansar	1978
23	Nishat	1978
24	Tarun	1978
25	Trikuta	1978
26	Type 41	1978
27	Chandan Makka Safed-2	1982
28	Chandan Makka-1	1982
29	Chandan Makka-3	1982
30	Kiran (J 660)	1982
31	Navin (D-741)	1982
32	Pratap (J-54)	1982
33	Shweta	1982
34	VL Amber pop Corn	1982
35	VL Makka-16	1982
36	African Tall	1983
37	Composite laxmi	1983
38	Navjot	1983
39	Composite Hemant	1985
40	Composite Suvan	1985
41	D-765	1985
42	Diara-3 (ZFS-3)	1985
43	Farm Sameri	1985
44	Pratap-1	1985
45	Co-1 (UMC-5)	1986
46	Kanchan (D-771)	1986
47	Arun	1988
48	Dhawal	1988
49	Gujarat Makai-1	1988
50	Harsha Composite	1988
51	MCU 508	1988
52	NLD white	1988
53	Prabhat	1988
54	Pusa Composite-1 (EFC)	1988
55	Pusa Composite-2 (LVA 61-80)	1988
56	Renuka	1988
57	VL Makka-88	1988
58	Madhuri	1990
59	Parvati	1990
60	Varun	1990
61	C15	1994
62	C6	1994
63	C8	1994
64	Kesari	1994
65	Megha	1994
66	Mahi Kanchan	1995
67	Shakti-1	1997
68	VL Sankul Makka	2003
69	VL Baby Corn 1	2004
b. Hybrids		
1.	Deccan	1961
2.	Ganga 1	1961
3.	Ganga 101	1961
4.	Ranjit	1961
5.	VL 54	1962

S. No.	Name of the cultivar	Year of release
6.	Ganga Safed 2	1963
7.	Hi-Starch	1963
8.	Ganga 3	1964
9.	Him 123	1964
10.	Ganga 5	1968
11.	Ganga 7	1968
12.	Ganga 4	1971
13.	VL 42	1972
14.	Deccon 101	1975
15.	Ganga Hybrid Makka-9	1980
16.	HIM-128	1980
17.	Deccan 103 (EH-400175)	1982
18.	KMH-1	1982
19.	Sangam	1982
20.	VL Makka-41	1982
21.	Deccan Hybrid Makka-1	1988
22.	Ganga 11	1988
23.	Ganga 11 (EH 5131)	1988
24.	Sartaj	1988
25.	Surya (D765xD787)	1988
26.	Deccan 105	1990
27.	DHM-105 (EH 40184)	1990
28.	Trishulata	1991
29.	Co-H-2	1993
30.	DHM 107	1993
31.	DHM 109	1994
32.	KH 528	1994
33.	Rajendra hybrid makka 1	1994
34.	SSM 510	1994
35.	KH 598	1995
36.	PAC 9112	1995
37.	PAC 9735	1995
38.	Dharwad Makka 1	1996
39.	KH 5981	1996
40.	KH 5991	1996
41.	Paras	1996
42.	Rajendra hybrid makka2	1996
43.	3058 (Y 1402 K)	1997
44.	Bio 9681	1997

S. No.	Name of the cultivar	Year of release
45.	COH 3	1997
46.	Him 129	1997
47.	JK 2492	1997
48.	KH 9451	1997
49.	MMH 133	1997
50.	MMH 69	1997
51.	PAC 701	1997
52.	PAC 705	1997
53.	PAC 705	1997
54.	Prakash	1997
55.	Pro 311 (4640)	1997
56.	Pusa Early Hybrid Makka-1	1997
57.	Pusa Early Hybrid Makka-2	1997
58.	SSF 9374	1997
59.	X 1123 G (3342)	1997
60.	Parkash	1999
61.	Vivek hybrid 4	1999
62.	Vivek hybrid 5	1999
63.	HHM 1	2000
64.	HHM 2	2000
65.	JH 3459	2001
66.	Pusa Hy3	2001
67.	Shaktiman 1	2001
68.	Shaktiman 2	2001
69.	Vivek Maize Hy9	2001
70.	Buland Hy	2002
71.	Sheetal Hy	2002
72.	HQ 1	2003
73.	HQ 2	2003
74.	PMH 19	2003
75.	Pratap Hybrid Makka-1	2003
76.	Amber Shakti	2004
77.	Deccan 115	2004
78.	Pusa Early Hy5	2004
79.	Vivek 15	2004
80.	Vivek 17	2004

Source: DMR (2005)

4. SORGHUM (1968–2002)

S. No.	Name of the cultivar	Year of release
	a. Varieties	
1	CSV1	1968
2	M35-1	1969
3	CSV 2	1974
4	CSV 3	1974
5	CSV 4	1974
6	CSV 5	1974
7	CSV 6	1974
8	CSV7R	1974
9	SB 1066	1976
10	Mothi	1978
11	JJ 235	1978
12	CO 21	1978
13	CO 22	1978
14	CSV8R	1979
15	CO 23	1979
16	SB 1079	1979
17	C024	1980
18	SB 905	1981
19	SPV 235	1981
20	CSV 9	1982
21	GJ35	1982
22	GJ 108	1982
23	SPV 245	1982
24	CSV 10	1983
25	Swati**	1984
26	Varsha	1984
27	SPV297	1984
28	SPV 96	1984
29	GJ36	1984
30.	SPV655	1984
31	CSV 11	1985
32	Co 26**	1985
33	CO 25	1985
34	GJ9	1985
35	GJ 37	1987
36	CSV 13	1988
37	NTJ1	1989
38	SAR1	1989
39	UP Chari 3	1989
40	Pant Chari 3	1989
41	SPV669	1990
42	DSV1	1990
43	NTJ2	1990
44	N 14	1990
45	JJ 741	1991
46	CSV14R	1992
47	Paiyur	1992
48	K9	1993
49	PKV400	1993
50	DSV 3	1993
51	DSV2	1993
52	HES4	1994
53	Sel.3	1995
54	K 10	1995
55	JJ 938	1995
56	JJ939	1995
57	GJ38	1995
58	GJ39	1995
59	CSV 15	1996
60	Jawahar jowar 938	1996
61	ICSV745	1996
62	BSR1	1997
63	GJ40	1997
64	DSV5	1997
65	APK1	1997
66	DSV4	1998
67	ICI 501	1998
68	GJ41	1999
69	JJ 1041	1999
70	CSV216R	2000
71	NTJ3	2000
72	Mahabeej 7	2000
73	RSLG262.	2000
74	Parbhani Sweta	2000
75	SPV840	2001
76	Paiyur 2	2001
77	CO (S) 28	2001

S. No.	Name of the cultivar	Year of release
b. Hybrids		
1	CSH1	1964
2	CSH2	1965
3	CSH3	1970
4	Kovilpatti Tall	1970
5	CSH4	1973
6	CSH5	1975
7	CSH6	1977
8	CSH7R	1977
9	CSH8R	1977
10	C0H3	1981
11	GSH1	1981
12	CSH9	1983
13	CSH10	1984
14	GSH1	1985
15	CSH11	1986
16	CSH 12R	1986
17	SPH 388	1990
18	CSH 13R	1991
19	CSH14	1992
20	C0H4	1993
21	CSH13 K&R	1995
22	CSH15R	1995
23	MLSH 296	1997
24	CSH16	1997
25	CSH17	1998
26	CSH18	1999
27	PSH1	1999
28	JKSH 22	1999
29	CSH 19R	2000
30	ASH 1	2001
31	DSH 4R	2002

Source: NRCS (2005)

5. SUNFLOWER (1972–2004)

S. No.	Name of the cultivar	Year of release
a. Varieties		
1	EC-68414 (Peredovik)	1972
2	K1	1972
3	K2	1977
4	EC-68415(Armavirkij-3497)	1980
5	EC-69874 (Amravertz)	1980
6	Morden	1982
7	Rumsun Record	1982
8	CO-1	1983
9	Surya (PKV-SUF-72-37)	1983
10	CO-2	1986
11	SS 56	1994
12	TNAUSUF 7 (CO4 / 1995)	1994
13	GAUSUF 15 (Guj. Sun-1)	1995
14	PKVSF-9 (AKSF-9)	1996
15	PAC-47	1997
16	TNAUSUF-10 (CO 3 / 1994)	1997
17	LS-11 (Sidheshwar)	1999
18	DRSF 108	2004

S. No.	Name of the cultivar	Year of release
b. Hybrids		
1	BSH-1	1980
2	APSH 11	1988
3	LDMRSH-1 (LSH-1)	1991
4	LDMRSH3- (LSH-3)	1991
5	KBSH-1	1992
6	PSFH-67	1993
7	PKVSH 27	1996
8	DSH-1	1998
9	TCSH 1	2000
10	KBSH-41	2002
11	KBSH-42	2002
12	KBSH-44	2003
13	NDSH-1 (NDSH-15)	2003
14	LSFH – 34 (Maruti)	2003
15	RSFH-1	2004
16	DRSH (PCSH243)	2004

Source: Damodaram and Hegde (2005)

6. SOYBEAN (1970–2004)

S. No.	Name of the cultivar	Year of release
1	Kalitur	1971
2	Davis	1973
3	Clark 63	1973
4	Lee	1973 / 74 / 75
5	Ankur	1976
6	Hardee	1976
7	Alankar	1978
8	Type-49	1978
9	Improved Pelican*	1979
10	Punjab-1	1975 / 78
11	Bragg	1969 / 71 / 73 / 75 / 78
12	KHSB-2 Sneha	1979
13	Shilajeeth	1980
14	Pusa 40	1981
15	Durga (JS 72-280)	1982
16	Gaurav (JS72-44)	1982
17	Co-1	1982
18	JS-2	1982
19	KM-1	1982
20	Pusa-22	1983
21	Birsa soy-1	1983
22	Gujarat Soybean-1 (J-231)	1983
23	Gujarat Soybean- (J-202)	1983
24	PK-262	1983
25	PK-327	1983
26	JS-76-205	1984
27	MACS-13	1985
28	Moneta	1985
29	PK-308	1985
30	Pusa-37	1985
31	VL-Soya-1	1985
32	PK-416	1986
33	PK-472	1986
34	JS-75-46	1987
35	Pusa-24(DS-74-24-2)	1987
36	Pusa-16(DS-73-16)	1987
37	Shivalik(HIM SO-333)	1987
38	Pant Soybean-471	1988
39	Pusa-20 (DS-74-20-2)	1988
40	VL-Soya-2	1989
41	MACS-58	1989
42	ADT-1 (UGM-33)	1990

S. No.	Name of the cultivar	Year of release
43	SL-4	1990
44	Pant Soybean-564	1991
45	JS-80-21	1991
46	JS-71-5	1991
47	MACS-124	1992
48	MACS-57	1992
49	JS-335 (Jawahar Soybean)	1994
50	JS79-81 (Jawahar Soybean)	1994
51	VL-Soya-21	1996
52	MAUS-2 (Pooja)	1997
53	Co-2	1997
54	NRC-12 (Ahilya-2)	1997
55	NRC-2 (Ahilya-1)	1997
56	Pant Soybean-1024	1997
57	Pant Soybean-1029	1997
58	NRC-7 (Ahilya 3)	1997
59	Pant Soybean-1042	1997
60	KB-79 (Sneha)	1997
61	SL-295	1997
62	JS-90-41	1999
63	MACS-450	1999
64	MAUS-32 (Prasad)	2000
65	MAUS-47(Parbhani Sona)	2000
66	Pant Soya – 1092	2000
67	VL-Soya 47	2000
68	Hara soy(Himso-1563)	2001
69	Indira Soya-9	2001
70	LSB-1	2001
71	NRC-37 (Ahilya 4)	2001
72	JS 93-05(Jawahar Soybean)	2002
73	MAUS 61 (Pratikar)	2002
74	Pratap Soya(RAUS 5)	2002
75	MAUS 61-2 (Pratista)	2002
76	MAUS 71 (Samrudhi)	2002
77	Palam Soya (P-30-1-1)	2003
78	TAMS-38	2003
79	PS 1241	2003
80	MAUS-81 (Shakti)	2003
81	SL-525	2004
82	Phule Kalyani (DS-228)	2004

Source: National Research Centre for Soybean (2005)

7. POTATO (1963–2005)

S. No.	Name of the cultivar	Year of release
1.	Kufri Neela	1963
2.	Kufri Sindhuri	1967
3.	Kufri Chandramukhi	1968
4.	Kufri Jyoti	1968
5.	Kufri Jeevan	1968
6.	Kufri Alankar	1968
7.	Kufri Sheetman	1968
8.	Kufri Naveen	1968
9.	Kurfri Chamatkar	1968
10.	Kufri Kasigaro	1968
11.	Kufri Muthu	1971
12.	Kufri Lauvkar	1972
13.	Kufri Dewa	1973
14.	Kufri Badshah	1979
15.	Kufri Bahar	1980
16.	Kufri Lalima	1982
17.	Kufri Sherpa	1983
18.	Kufri Swarna	1985
19.	Kufri Megha	1989
20.	Kufri Ashoka	1996
21.	Kufri Jawajar	1996
22.	Kufri Sutlej	1996
23.	Kufri Chipsona-1	1998
24.	Kufri Chipsona-2	1998
25.	Kufri Pukhraj	1998
26.	Kufri Giriraj	1999
27	Kufri Anand	1999
28.	Kufri Kanchan	1999
29.	Kurif Surya	2005
30.	Kufri Arun	2005
31	Kurfi Pushkar	2005
32.	Kurfi Shailja	2005

Source: Garg et al. (1990); Gaur et al. (1999); CPRI (2005)

8. COTTON (1970–2005)

S. No.	Name of the cultivar	Year of release
	a. Varieties	
1	Badnawar 1	1970
2	Maljari	1970
3	MCU 6	1970
4	3870 SB	1970
5	Narmada (A-51-9)	1971
6	Bhagya	1971
7	Hampi	1971
8	K 8	1972
9	J 34	1973
10	G 27	1973
11	Jai	1973
12	RS 89	1974
13	Indore 1	1974
14	G. Cot.100	1974
15	Virnar	1974
16	CPH 2	1975
17	Fedraj(IC1824)	1976
18	MCU 5	1976
19	Godawari (NHH1)	1976
20	H 14	1976
21	MCU 8	1976
22	J 205	1978
23	F 414	1978
24	H 655C	1978
25	H 777	1978
26	HD 11	1978
27	Bikaneri Narma	1978
28	SH 131	1978
29	Sujay	1978
30	DHY 286	1978
31	AKH 4	1978
32	Jyoti	1978
34	Amaravathi (AV 1661)	1978
35	Sangam (V14)	1978
36	Fedraj	1978

S. No.	Name of the cultivar	Year of release
37	Mahanandi (355-E6)	1978
38	Srisainam	1978
39	Suvin	1978
40	Saraswathi (12009)	1978
41	Srisailam	1978
42	SRT 1	1978
43	Nimbkar 1	1978
44	GS 23	1978
45	G.ageti	1978
46	DB 3 -12	1979
47	LH 357	1980
48	Eknath	1980
49	Mahalakshmi	1980
50	MCU 9	1980
51	PA 32	1980
52	DS 51	1980
53	ADB 332	1981
54	Vikram Jawahar kapas2	1981
55	AHH 468	1981
56	DS 59	1981
57	LH 372	1982
58	LD 133	1982
59	LD 230	1982
60	Ganganagar Ageti	1982
61	Khandwa 2	1982
62	G.Cot.10	1982
63	V 797	1982
64	G 46	1982
65	Sharada (CPD - 8-1)	1982
66	Jayadhar	1982
67	Suyodhar	1982
68	Vijayalakshmi (NA 247)	1982
69	Bhagyalakshmi (NHB 380)	1982
70	K 9	1982
71	Sarada (CBD8-1)	1982
72	DS 56	1982
73	Radhy 1	1983
74	AKA 5	1983
75	Soubhagya-DS58	1983
76	Raichur 51	1983
77	KC 1	1983

S. No.	Name of the cultivar	Year of release
78	LRA 5166	1983
79	Vikram	1984
80	G.Cot.12	1984
81	G.Cot.13	1984
82	MCU 7	1984
83	MCU 10	1984
84	MCU 5 VT	1984
85	G.Cot.11	1984
86	G.Cot.102	1984
87	Poternia (NH 239)	1984
88	PKV 081	1984
89	SIMA 1	1984
90	TNB 1	1984
91	F 286	1985
92	DS 1	1985
93	RS 513	1985
94	Lohit	1985
95	BC 761	1985
96	Khandwa 3	1985
97	Purnima	1985
98	Rohini (NA 48)	1985
99	NA 247	1985
100	Ajantha (DB-3-12)	1985
101	Supriya	1985
102	H 888	1985
103	LH 900	1985
104	Nira	1986
104	Pavan	1986
105	Krishna	1986
106	K 10	1986
107	G.Cot.14	1986
108	Nira (KOP-498)	1986
109	DCH 337	1986
110	F 505	1987
111	LH 900	1987
112	Kanchana (LPS 141)	1987
113	NH 210	1987
114	SVPR 763	1987
115	D 327	1987
116	HS 45	1988
117	Priya (NA 920)	1988

S. No.	Name of the cultivar	Year of release
118	Hybrid 8	1988
119	Pusa 595B	1988
120	BCS 23-18-7	1988
121	LH 886	1989
122	LD 327	1989
123	DS 5	1989
124	RG 8	1989
125	Vikas	1989
126	Pusa 31	1989
127	AKH 081	1989
128	Ganesh	1989
129	Gowri	1989
130	MCU 11	1989
131	DS 21	1989
132	PH 93	1989
133	Gowri (AH-107)	1989
134	LH 1134	1990
135	G.cot.15	1990
136	Priya	1990
137	Abadhita	1990
138	Arunabha	1990
139	Jhurer	1990
140	ACP 71	1990
141	HS 6	1991
142	RST 9	1992
143	Anjali (LRK 516)	1992
144	F 1054	1993
145	H 974	1993
146	AKA 8401	1993
147	Namdeo (PA 141)	1993
148	JLH 168	1993
149	Kiran	1993
150	ADT 1	1993
151	Paiyur 1	1993
152	SVPR 1	1993
153	NA 1325	1993
154	F 846	1994
155	Kaushal (CICR HH-2)	1994
156	LK 861	1995
157	L 389	1995

S. No.	Name of the cultivar	Year of release
158	Renuga (NH 452)	1995
159	LH 1556	1996
160	LD 491	1996
161	HD 107	1996
162	RS 875	1996
163	G.Cot.16	1996
164	G.Cot.17	1996
165	PKV Rajat	1996
166	Renuka	1996
167	PA 183	1996
168	Arogya	1996
169	Sawata (PA 183)	1996
170	Ramp 155	1996
171	F 1378	1997
173	H 1098	1997
174	Pusa 8-6	1997
175	JCC 1	1997
176	Jawahar Tapti	1997
177	G.cot.19	1997
178	KC 2	1997
179	SVPR 2	1997
180	K 11	1997
181	Surabhi	1997
182	HS 182	1997
183	RS 875	1997
184	Raghavendra	1998
185	DDCC 1	1998
186	PA 235	1999
187	Narasimha	1999
188	Turab (PA 255)	1999
189	NH 545	1999
190	HD 123	2000
191	RS 810	2000
192	L 603	2000
193	L 604	2000
194	Aravinda	2000
195	MCU 12	2000
196	SVPR 3	2000
197	CAD	2001
198	RG 18	2001
199	Vagad Kalyan	2001

S. No.	Name of the cultivar	Year of release
200	G.Cot.18	2001
201	G.Cot.21	2001
202	AKA 7	2001
203	Pratima	2001
204	Sahana	2001
205	RAMPBS 155	2001
206	Sumangala	2001
207	LD 694	2001
208	Sarvottam	2001
209	H 1117	2002
210	RS 2013	2002
211	JK 4	2002
212	G. Cot.23	2002
213	PA 402	2003
214	DLSA 17	2003
215	MCU 13	2004
216	Veena	2005
217	NH.545	2005
218	Parbhani Turab (PA. 225)	2005
b. Hybrids		
1	NHB 1	1972
2	Hybrid 4 (Shankar - 4)	1974
3	Varalaxmi	1975
4	CBS 156	1976
5	Savithri (RHR 253)	1978
6	G.Cot.Hy 6	1979
7	KCH 1	1980
8	ABH 4208	1981
9	JKHY 1	1982
10	JK Hy 11	1982
11	NHB 80	1982
12	DCH 32 (Jayalaxmi)	1983
13	Godawari	1985
14	NHH-44	1985
15	G. Cot. DH 7	1986
16	Sampada	1986
17	Saropada (RHH 195)	1986
18	Savita	1987
19	G. Cot. Hy 8	1988

S. No.	Name of the cultivar	Year of release
20	Lam Hybrid 1	1989
21	HB 224	1989
22	G. Cot. DH 9	1990
23	NHB 12	1990
24	TCHB 213	1991
25	Kirti (CICR HH-1)	1992
26	NHH 302	1992
27	Jayashakti (DDH 2)	1992
28	PKV HY-2	1993
29	NHH-302	1993
30	NHH 390	1993
31	LDH 11	1994
32	Fateh	1995
33	TM 1312 (Surya)	1995
34	HHH 81	1996
35	Maru Vikas	1996
36	G.Cot.Hy 10	1996
37	PKV HY 3	1996
38	PHA 46	1996
39	DHB 105	1996
40	Omshankar	1997
41	JKHY 2	1997
42	DHH 11	1997
43	Sruthi	1997
44	LHH 144	1998
45	AAH 1	1999
46	Ganga	1999
47	LAHH 4	2000
48	RHB 0388	2000
49	PKV HY 4	2001
50	HHH 223	2002
51	Phule 492	2002
52	Phule 388	2002
53	CSHH-198 (Shresth)	2005
54	CISAA-2 (CICR-2)	2005
55	PKV DH - 1	2005
56	PKV Hy.5	2005

Source: CICR (2005); Singh (2004)

9. SUGARCANE (1970–2005)

S. No.	Name of the cultivar	Year of release
1	Co 6304	1970
2	Co 1158	1972
3	CoC 671	1975
4	CoJ 64	1976
5	CoJ 67	1976
6	CoA 7701	1977
7	CoC 771	1977
8	CoC 772	1977
9	CoSi 776	1977
10	BO 89	1977
11	BO 90	1977
12	CoC 774	1977
13	CoC 775	1977
14	CoC 777	1977
15	CoC 778	1977
16	CoC 779	1977
17	CoG 773	1977
18	CoH 7803	1978
19	BO 91	1978
20	BO 99	1978
21	Co 1253	1979
22	Co 1307	1979
23	Co 1305	1980
24	CoC 8001	1980
25	CoR 8001	1980
26	CoS 687	1980
27	Co 62197	1981
28	Co 62207	1981
29	Co 6415	1981
30	Co 6617	1981
31	Co 7202	1981
32	Co 7218	1981
34	Co 7219	1981
35	CoS 767	1981
36	Co 7314	1981
37	Co 7318	1981
38	CoS 7918	1981
39	Co 6806	1981
40	CoC 8201	1982
41	Co 7508	1982
42	Co 7224	1982
43	CoJ 79	1982
44	CoS 802	1982
45	CoS 8118	1982
46	CoT 8201	1982
47	Co 7704	1983
48	CoS 8315	1983
49	CoA 7602	1983
50	CoA 8401	1984
51	CoA 8402	1984
52	CoLk 8001	1984
53	CoM 7125	1984
54	CoS 8422	1984
55	BO 102	1984
56	BO 104	1984
57	BO 767	1984
58	CoS 837	1984
59	UP 1	1984
60	UP 3	1984
61	Co 7706	1985
62	CoS 8119	1985
63	CoS 8016	1985
64	CoC 85061	1985
65	Co 8014	1986
66	CoJ 76	1986
67	CoJ 77	1986
68	CoJ 78	1986
69	CoJ 81	1986
70	BO 106	1986
71	BO 108	1986
72	BO 109	1986
73	CoSi 86071	1986
74	CoC 86062	1986
75	CoS 8407	1986
76	CoS 8408	1986
77	UP 6	1987
78	CoS 8432	1987
79	CoS 8436	1987
80	CoS 8312	1987
81	CoS 8009	1987

S. No.	Name of the cultivar	Year of release
82	Co 8013	1987
83	BO 110	1988
84	CoS 85223	1988
85	CoS 86218	1989
86	CoS 8439	1989
87	CoS 87220	1989
88	CoS 8206	1989
89	CoS 8207	1989
90	BO 116	1989
91	BO 120	1989
92	CoC 90063	1990
93	Co 8021	1990
94	UP 12	1990
95	UP 15	1990
96	CoS 88216	1990
97	CoC 91061	1991
98	Co 8338	1991
99	Madhuri	1991
100	CoS 88230	1991
101	CoS 90265	1991
102	CoS 90269	1991
103	CoC 92061	1992
104	Co 83062	1992
104	Thirumadhuram	1992
105	CoS 91269	1992
106	CoS 92254	1992
107	CoS 92263	1992
108	UP 22	1992
109	CoJ 83	1992
110	CoJ 84	1992
111	CoG 93076	1993
112	CoS 87231	1993
113	CoS 87222	1993
114	CoS 87225	1993
115	CoS 91230	1993
116	CoS 91248	1993
117	CoS 93218	1993
118	CoSe 91423	1993
119	UP 39	1993
120	Co Pant 211	1993
121	CoG 94077	1994
122	CoG 95076	1995
123	CoP 9206	1995
124	CoSi 95071	1995
125	CoJ 82	1995
126	CoS 93278	1995
127	CoS 94257	1995
128	CoS 87216	1995
129	CoSe 92234	1995
130	CoSe 93232	1995
131	CoSe 94423	1995
132	CoS 93259	1996
133	CoS 95255	1996
134	UP 9529	1996
135	UP 9530	1996
136	CoLK 8102	1996
137	CoPant 84211	1996
138	CoSi 96071	1996
139	Madhurima	1996
140	CoP 9301	1996
141	CoN 91132	1996
142	CoP 9302	1996
143	CoS 96260	1997
144	CoSe 93234	1997
145	CoSe 95427	1997
146	CoSe 95435	1997
147	BO 130	1997
148	Madhumathi	1998
149	CoC 98061	1998
150	CoSi 98071	1998
151	CoPant 84212	1998
152	CoS 95222	1998
153	CoS 96258	1998
154	CoSe 95436	1998
155	CoC 99061	1999
156	CoJ 86	1999
157	CoSe 98231	1999
158	CoS 96268	1999
159	CoS 97264	1999
160	CoS 8436	2000
161	Co 8371 (Bhima)	2000
162	Co 85004 (Prabha)	2000

S. No.	Name of the cultivar	Year of release
163	Co 86032 (Nayana)	2000
164	Co 87025 (Kalyani)	2000
165	Co 87044 (Uttara)	2000
166	Co 87263 (Sarayu)	2000
167	Co 87268 (Moti)	2000
168	Co 91010 (Dhanush)	2000
169	CoM 88121 (Krishna)	2000
170	Co Pant 90223	2000
171	CoS 1230 (Raseeli)	2000
173	CoJ 85	2000
174	CoS 843	2000
175	CoN 85134	2000
176	CoN 95132	2001
177	BO 128 (Pramod)	2001
178	Co 89029 (Gandak)	2001
179	CoH 2201 (Haryana92)	2001
180	CoSe 92423 (Rajbhog)	2001
181	CoSe 95422 (Rasbhari)	2001
182	CoPant 90223	2001
183	Viswamithra (87A298)	2002
184	Durga Bhavani (83V15)	2002
185	Vasuda (83R23)	2002
186	Madu (84A125)	2002
187	CoJ 88	2002
188	Krishna (91V83)	2002
189	CoS 96275	2003
190	CoS 97261	2003
191	UP 0097	2003
192	CoSe 00235	2003
193	CoSe 01235	2003
194	CoS 95255	2003
195	CoSe 92434	2003
196	CoSe 96436 Jalper	2003
197	CoC (SC) 22	2004
198	Co 94008 (Shyama)	2004
199	CoS 94270 (Sweta)	2004
200	CoS 96269	2004
201	CoS 99259	2005
202	CoSi (SC) 6	2005
203	CoG (SC) 5	2005

Source: AICRP on Sugarcane (2006); SBRI (2006); SRS (2006)

3

IRRIGATION*

3.1 Introduction

Water is the lifeline of agriculture and a substantial proportion of total available water resources in India are used for irrigation purposes. Some of the noteworthy achievements in the irrigation sphere in India are the magnificent dams across rivers with their vast network of canals, shallow and deep tubewells in the plains, and borewells in hard rock areas. Several technologies, major and minor, have played a crucial role in the development of irrigation in the country with regard to harnessing, distributing and managing water resources as well as in conserving and quantifying available water. In this chapter, the attempt is to provide an overview of irrigation development since the 1950s and to highlight the technologies that have made a significant contribution towards it, particularly in the post-Independence period.

The design and construction of dams in India have undergone several modifications based on new scientific inputs and experience over the years. Lining of canals using several scientific methods is said to have resulted in significant reduction in water loss in many canal systems in the country. Moreover, technology has enabled construction of large dams even in areas susceptible to seismic activity, which is a major breakthrough, particularly with regard to the flood prone northeastern States. As regards sub-surface irrigation, high speed drilling technology has replaced traditional shallow dug wells by modern deep borewells in hard rock areas. The spread of tubewell technology has brought large tracts of the plains, particularly the Indo-Gangetic plains, under irrigation. Pumping technology has undergone major strides from low cost zero energy pedal pumps in shallow aquifers to high power pumps to reach deep aquifers in the hard rock areas. The use of several computer simulation models, remote sensing and GIS tools along with advanced imaging techniques such as polarimetric SAR, radar interferometry, ground penetrating radar (GPR) and nuclear magnetic resonance techniques, as also stereoscopic measurements in the optical region have replaced the traditional methods of water resource quantification and management. Geophysical tools are quite useful in deciphering groundwater occurrence and its quality without undertaking the costly and strenuous task of drilling wells. Modern geophysical prospecting using resistivity methods are increasingly used instead of traditional water divining for better success rates in groundwater prospecting. In recent years, the use of remote sensing images and data in conjunction with geophysical methods is being practised by several state government agencies for identifying location of drinking water wells and groundwater recharge zones. In the areas of water conservation, the list of technologies is quite long, ranging from improvements in water conveyance to water application and on-farm conservation methods. Rainwater harvesting, groundwater recharge and micro-irrigation technology are some, which have tremendous potential for water conservation in addition to other benefits.

* Contributed by Dr. Indumathi M. Nambi, Assistant Professor, Indian Institute of Technology, Chennai

Expansion of irrigation in the country is in part related to a conscious policy decision of the government to invest in irrigation works and in part to development of technologies, such as the drilling technology, leading to investment by individual farmers. Over the last five decades, net irrigated area has more than doubled and this expansion underlies the significant improvement in agricultural productivity and production in the country.

3.2 Technological Interventions in the Irrigation Sector[1]

In this section, important technological interventions that have come about in the irrigation sphere during the post-Independence era are discussed.

3.2.1 Technological Inputs in Surface Irrigation Systems

Surface irrigation involves a whole range of technologies, such as hydrological studies for design of dams, sluices and canals, geotechnical investigations, and surveying and construction technology. It is not possible to isolate one particular technology as the sole contributor for the growth of canal irrigation. The contribution made by each of these technologies has translated into bigger and better technologically sound, structurally safe and functionally efficient surface irrigation projects.

Research in the areas of structural engineering, geotechnical engineering and hydrological sciences has vastly improved the construction of the various components of our major and medium irrigation projects such as dams and canals. The interventions have been two pronged: both in the hardware such as design and construction technology and more importantly in the software, i.e., the hydrological, which is the basis for the structural design. The innovations in design methodology in incorporating seismic loads have enabled construction of dams in earthquake-prone regions. Technology such as roller-compacted concrete and concrete premixes have revolutionised and greatly improved the quality of reinforced cement concrete (RCC) constructions. Unlike the traditional block-by-block dam construction method, RCC dams are built in layers. This not only saves time but also results in cost savings. Moreover, in RCC construction, cement is replaced to a great extent by fly-ash which results in further cost savings. Canal lining technology, by using a variety of materials such as tiles, geofabrics and cement paving, leads to considerable water savings as infiltration losses are prevented. Hydrological studies involve the understanding of the hydrological cycle of the region such as rainfall-runoff estimations, groundwater infiltration-recharge quantifications, flood forecasting, sedimentation rates, etc., which are the fundamental parameters for design of irrigation development projects. These studies and their results enable quantification of water availability in surface water bodies and subsurface aquifers as a result of the changes in the hydrological systems. With the advances in the field of stochastic hydrology and the advent of high-speed computers, mathematical modelling of the randomly varying natural hydrological phenomenon is accomplished. This has greatly enhanced the accuracy of runoff and flood predictions and resulted in cost effective designs compared to those based on empirical formulae, which only produce a conservative estimate of the maximum flood that has occurred.

[1] The selection of technologies has been based on discussions with experts and scientists in the various fields related to irrigation. Some of them are: Professor A.Vaidyanathan, Honorary Fellow, Centre for Development Studies, Trivandrum; Professor Palanichamy, TNAU, Coimbatore; Dr. A.K.Singh, IARI, New Delhi; Professor K. Srinivasan, IIT-M, Chennai; Professor P. Gomathinayagam, Anna University; and others from IWMI, Hyderabad.

3.2.2 Technological Interventions in Groundwater Irrigation

In the case of groundwater irrigation, the boom in tubewells and borewells since the mid 1960s was possible with the advent of high-speed drilling technology. The tubewell revolution in the Indo-Gangetic plains was catalysed by the spread of percussion and rotary drilling technology particularly adopted for the softer unconsolidated formations. The borewell revolution in the peninsular region was triggered by the advent of hard rock drilling technology primarily brought into India for drilling drinking water boreholes in consolidated formations. It triggered the development of a host of other associated technologies such as geophysical prospecting, pumping technology, etc. With the geology of two-thirds of the country delineated as hard rock, this technology has had tremendous impact by bringing large, previously arid areas under irrigation. Drilling technology replaced traditional shallow dug wells by modern tubewells in sandy formations and borewells in hard rock areas. The time taken to dig a well was drastically reduced from weeks to a matter of hours. In addition to technological interventions, various institutional interventions like government policies, rural electrification and rural credit facilities contributed towards the spread of tubewell and borewell irrigation in the country.

3.2.3 Water Management Technologies

Various technologies and strategies have evolved to conserve water and to mitigate the negative impacts of rapid irrigation development. Some of the strategies that have come up in the past two decades are:

1. Watershed development
2. Conjunctive use of surface and groundwater
3. Micro-irrigation
4. Remote sensing and GIS

3.2.3.1 Watershed Development

Watershed programmes comprise a set of technologies primarily for water and soil conservation. The major technologies involved are construction of location-specific rainwater harvesting structures such as check dams, percolation ponds, networked farm ponds, soil conservation measures such as field bunds and groundwater recharge structures such as subsurface dykes, vertical barrier walls, etc. Research on soil and water conservation was initiated as early as 1956 at the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun. The Ministry of Rural Development also initiated programmes like Drought-Prone Areas Programme and Desert Development Programme during the 1970s to address certain location-specific problems. An integrated watershed programme, initiated first through pilot projects over 19 watersheds in the country, was followed by the launch of the National Watershed Development Project for Rainfed Areas (NWDPRA) in 1986. There have also been several initiatives from non-governmental organisations and national level research bodies, such as ICAR, ICRISAT, etc.

3.2.3.2 Conjunctive Use of Surface and Groundwater

The conjunctive use of surface and groundwater has been a successful strategy for combating the dual problem of waterlogging in the canal command areas and overexploitation of groundwater. Conjunctive use is defined as the integrated development and operation of surface and groundwater in such a way as to enhance their combined output. During the lean monsoon years, groundwater is used to augment canal water supply. This enables multiple cropping in the command area, particularly benefiting the farmers at the tail end of the command area. Pumping groundwater also prevents waterlogging at the upstream command area by lowering the water table. In high monsoon years, the surface water is utilised to the maximum extent possible and excess water is used to augment the groundwater storage through wells. Thus, conjunctive use enables nullifying of the negative impacts of surface water irrigation by groundwater and vice versa, and the combined development can turn into an overall advantage. Computer- based simulation technology could play a vital role in scientifically planning conjunctive use in canal command, tank command and well command areas.

3.2.3.3 Micro Irrigation

Micro-irrigation, which is the controlled supply of water at the root zone of the crop (drip method) or aerial sprinkling at the vicinity of the plants (sprinkler method), enables substantial increase in water savings and irrigation efficiency. With the looming water scarcity situation and increasing demands for water, efficient use of irrigation water through micro-irrigation technology can have a huge positive impact. A recent advancement in the drip method is fertigation, where fertilisers are applied along with the water. Fertigation increases the efficiency of fertilisers significantly and results in fertiliser savings for various crops. Micro-irrigation has other indirect advantages, such as reduced energy requirement, improved pest and disease management, reduced labour requirement, feasibility of irrigating difficult terrains, suitability for problem soils, improved tolerance to salinity, etc.

3.2.3.4 Remote Sensing and GIS Technology

Satellite data provide information on rock types, landforms, geological structures (faults, folds, fractures, dykes, etc.), weathering, soil types, erosion, land use / land cover and surface water bodies (lakes, tanks, reservoirs), distribution of groundwater irrigated areas and their acreage. Such information when integrated into a Geographic Information System (GIS) environment has a wide range of applications. In the field of water resources and irrigation there are several areas where remote sensing is being applied currently for scientific planning, management and monitoring. Some of them are:

1. Hydrological studies which include rainfall estimation, forecasting and monitoring, hydrological modelling, urban hydrology and water balance models

2. Watershed conservation, planning and management, including watershed delineation, quantitative analysis of drainage network, watershed geology, soil mapping, lake and reservoir sedimentation studies

3. Flood plain management, including flood mapping, flood estimation and forecasting, disaster warning systems and flood damage assessment

4. Water resources development studies like location of potential sites for storage reservoirs, location of cross drainage works, inter-basin transfer of flood / surplus flow, impact of dams on land use, soil, groundwater, settlement, etc.

5. Irrigation management in command areas, including assessment of surface water resources, reservoir operation, identification, inventorying and assessment of irrigated crops, mapping areas affected by waterlogging, soil moisture estimation, irrigation scheduling, conjunctive use of surface and groundwater, detection of canal seepage, artificial recharge, detection of hydraulic leakages from dams and monitoring performance of irrigation projects

6. Groundwater studies such as groundwater exploration and targeting, identification of groundwater recharge zones, detection of springs and freshwater discharge to inland rivers and seabeds, and detection of hydro-geomorphological features like abandoned or buried channels and channel aquifers.

7. Drought monitoring, including identification of drought-affected areas and monitoring, drought impact assessment and drought prediction and monitoring

8. Other applications such as water quality mapping and monitoring, river morphology, saline water intrusion and estuarine studies, and coastal management

Remote sensing is currently being applied in several State and Central government sponsored projects successfully.

3.3 Overview of Irrigation Development in India

3.3.1 Conventional Sources of Irrigation

Modern irrigation technology ensures assured water supply throughout the year for agriculture, without having to depend on the monsoons. In the pre-colonial era, the main irrigation systems were river diversion works and tanks and dug wells that were managed by local communities. The colonial government expanded canal irrigation in India in a big way in the early 19th century. During the post-Independence era, the interventions have been varied at different time periods, catering to the demands and the water situation at the respective time points. The rapid growth in agricultural production in the country is largely related to the extension of irrigation in India. Creation of major, medium and minor irrigation works through the Five Year Plan periods, has led to significant development of irrigation potential in the country over the last five decades. **Table 3.1** and **Figure 3.1** below indicate the progress in irrigation potential in India.

Table 3.1: Development of Irrigation Potential (Cumulative) through Plan Periods

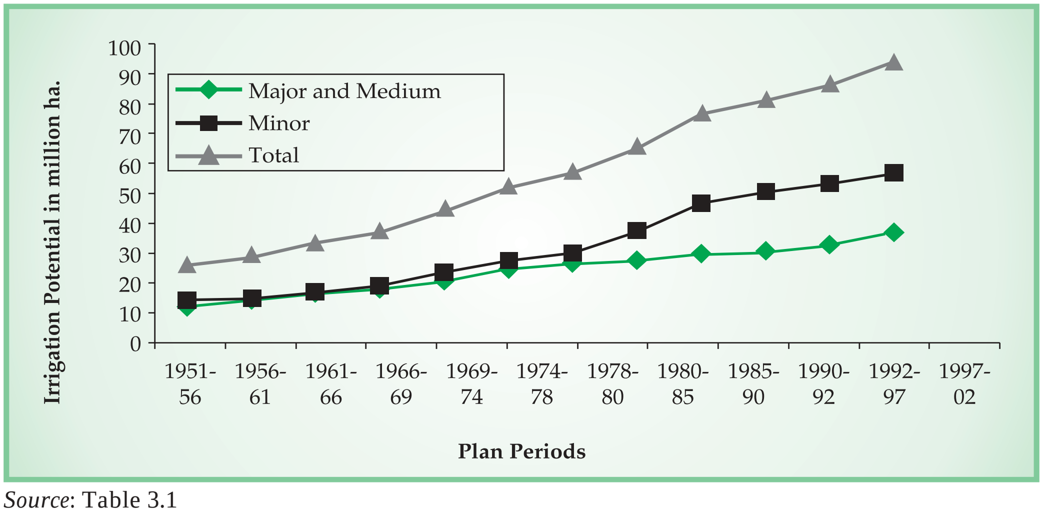
(million ha)

Plan Period	Major/Medium Irrigation		Minor Irrigation		Total Irrigation	
	Potential	Utilised	Potential	Utilised	Potential	Utilised
Pre-Plan	9.70	9.70	12.90	12.90	22.60	22.60
1951-56	12.20	10.98	14.06	14.00	26.26	25.04
1956-61	14.33	13.05	14.75	14.75	29.08	27.80
1961-66	16.57	15.17	17.00	17.00	33.57	32.17
1966-69	18.10	16.75	19.00	19.00	37.10	35.75
1969-74	20.70	18.69	23.50	23.50	44.20	42.19
1974-78	24.72	21.16	27.30	27.30	52.02	48.46
1978-80	26.61	22.64	30.00	30.00	56.61	52.64
1980-85	27.70	23.57	37.52	35.25	65.22	58.82
1985-90	29.92	25.47	46.61	43.12	76.53	68.59
1990-92	30.74	26.32	50.35	46.54	81.09	72.86
1992-97	32.96	28.44	53.30	48.80	86.26	77.24
1997-02	37.08	31.03	56.90	49.05	93.98	80.80

Note: Irrigation systems that have cultivable command areas greater than 10,000 ha are major works, between 2000-10,000 ha are medium works and less than 2000 ha are minor works. Minor works are further classified as those dependent on surface water and groundwater. (Raju et al., 2004)

Source: Planning Commission (Tenth Five Year Plan, 2002-07, Annexure 8.1.2)

Figure 3.1: Development of Irrigation Potential



Source: Table 3.1

Irrigation potential created in the country has increased more than fourfold since 1951. Till the Sixth Five Year Plan, the contribution to total irrigation potential was more or less equal from major / medium and minor irrigation works, while the importance of minor irrigation works increased rapidly from the 1980s onwards. The potential created is a result of the construction of major and medium irrigation projects (dams and canals) and minor irrigation schemes such as tanks, wells, canals and channels from rain-fed sources. It can also be interpreted as the design irrigation potential when these projects are envisaged.

In many of the projects, only major canals are constructed, unmindful of the inaccessibility of distant farmlands to the canal water. Large acres of land close to irrigation canals are out of reach of irrigation because there are not enough field channels. The potential utilised is the area of cultivable land actually having access to water from the irrigation projects. Hence, there is a significant gap between the potential created and the potential utilised. In the First Five Year Plan, potential utilised was 95 % of potential created and this percentage declined to 86 % during the Ninth Plan. Potential utilised as a percentage of potential created has been better for minor irrigation works through all the Plan periods.

The actual area irrigated by various sources as given in **Table 3.2** differs from the potential utilised presented in **Table 3.1**. This is likely to be related to the fact that the two sets of data are collected by two different sources: actual area irrigated by the Indian Agricultural Statistics and potential created and utilised by the Central Water Commission (CWC 2002). It is important to note that the pattern of growth provided by both the data sets is similar.

Table 3.2: Net Area Irrigated through Different Sources of Irrigation, India

(in '000 ha)

Triennium centred around the year	Canals	Tanks	Tubewells	Groundwater*	Other sources	Net Irrigated Area	Gross Irrigated Area
1951-52	8,613 (41.00)	3468 (16.51)	-	6,339 (30.17)	2,588 (12.32)	21,008 (100.00)	23,016 (100)
1961-62	10,568 (42.15)	4,651 (18.55)	431 (1.72)	7,430 (29.64)	2,420 (9.65)	25,070 (100.00)	28,631 (124)
1971-72	12,983 (41.22)	3,822 (12.13)	4,866 (15.45)	12,377 (39.30)	2,313 (7.34)	31,494 (100.00)	38,560 (168)
1981-82	15,808 (39.55)	3,165 (7.92)	10,212 (25.55)	18,593 (46.52)	2,406 (6.02)	39,971 (100.00)	51,006 (228)
1991-92	17,567 (35.57)	2,930 (5.93)	15,080 (30.53)	25,705 (52.04)	3,193 (6.46)	49,394 (100.00)	65,215 (283)
2000-01	16,049 (28.75)	2,476 (4.44)	22,318 (39.98)	34,397 (61.62)	2,901 (5.20)	55,823 (100.00)	76,240 (331)

Note: 1. * Groundwater refers to tubewells and other wells.
2. From the year 1993-94 onwards, data provided is provisional.
3. Figures in brackets in the last column refer to indices w.r. to 1951-52.
4. Figures in brackets in all other columns refer to percentage contribution of different sources of irrigation to NIA.

Source: www.agricoop.nic.in / statistics / sump2.htm

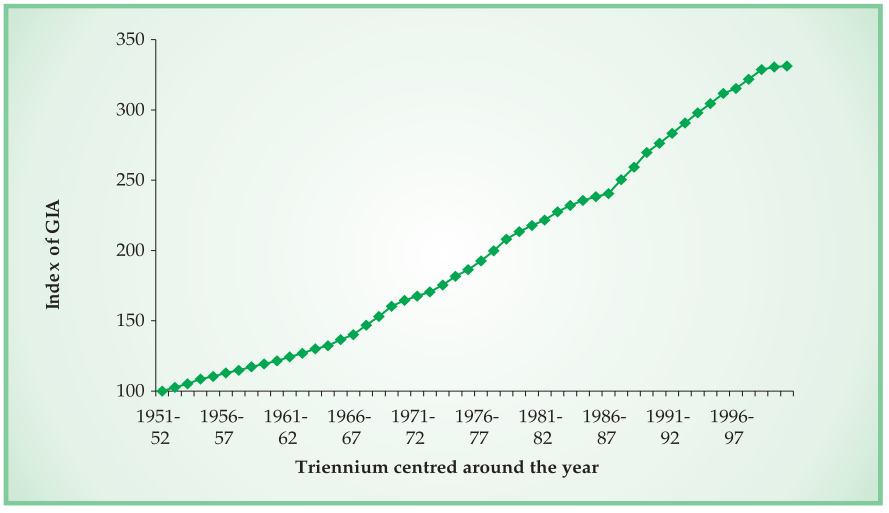
Table 3.2 corroborates the point that has been well documented in the literature, of the increasing importance of groundwater irrigation and the declining importance of surface irrigation in the overall irrigation scenario of the country. Surface irrigation, comprising canals and tanks, was the major source of irrigation in the early 1950s, accounting for nearly 57 % of net irrigated area. Over the years, the extent of area irrigated by tanks declined from 3.4 million hectares in 1951–52 to 2.5 million hectares in 2000–01. Around the same period, the area irrigated by canals has more or less doubled, from 8.6 million hectares to 16 million hectares. However, the relative importance of canals as a source of irrigation has declined sharply. Groundwater has emerged as an important source of irrigation, particularly since the 1960s.

Groundwater-based well irrigation systems are not only independently accessible for an average farmer in regions of high groundwater potential but also very dependable throughout the cropping season. In the late 1960s, harnessing groundwater through shallow tubewells in unconsolidated sandy formations started a new phase in irrigated agriculture. Also in the same period, hard rock drilling technology increased the number of borewells and dug-cum-borewells in the consolidated formations of the peninsular States, contributing significantly to the areas covered by well irrigation (Dhawan 1982). In the early 1960s, tubewell irrigation accounted for less than 6 % of total groundwater irrigation but this increased to nearly 40 % by 1971–72 and to 65 % by 2000–01. Together, surface irrigation by canals and groundwater irrigation technologies have contributed significantly to attaining the goals of extensive irrigation coverage. The total gross irrigated area of the country rose from 23 million hectares in 1951–52 to 76 million hectares by 2000–01, a more than three-fold increase. Analysing the development of irrigation in the country as a whole, three distinct stages are identified:

1. 1950–1965, when canal irrigation grew at a steady pace
2. 1965–1980, when tubewell and borewell irrigation picked up and grew along with canal irrigation, while area under tanks declined
3. 1980–2000, when canal irrigation stagnated and tubewells continued to grow. Revival of traditional irrigation such as tanks and dug wells, other important interventions such as watershed management, micro-irrigation, conjunctive usage of water resources, etc., also picked up momentum.

A more than three-fold increase in gross irrigated area reflects the extent of diffusion of irrigation across space and across seasons. Using gross irrigated area as an indicator to reflect irrigation diffusion, an index of irrigation diffusion for the period 1951–52 to 1998–99 for the irrigation sphere can be worked out. Using the triennium average of gross irrigated area for the years 1950–51 to 1952–53 as the base, the index has risen from 100 in the base year to 331 in triennium 1999–00 to 2001–02.

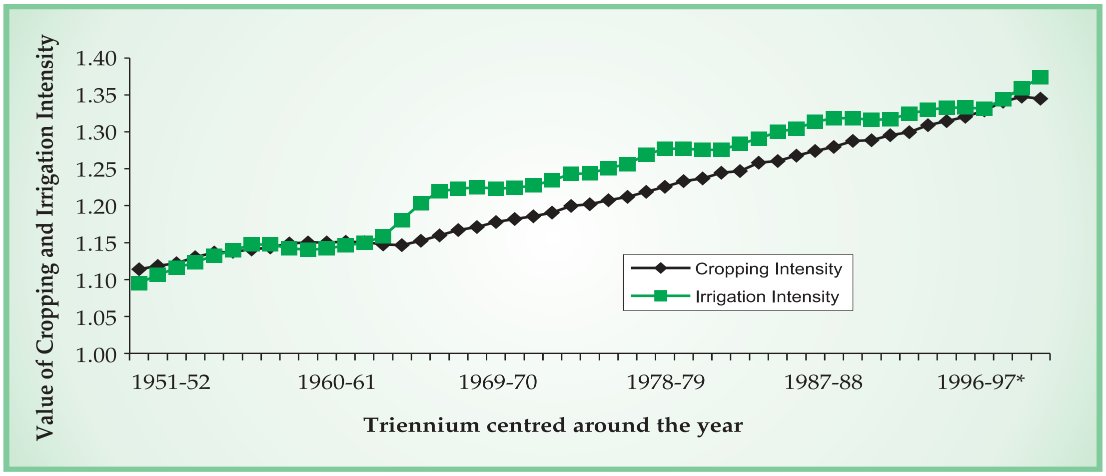
Figure 3.2: Irrigation Diffusion Index



Source: Agriculture Statistics (2002); http://www.agricoop.com

Irrigation intensity, which is the ratio of gross irrigated area to net irrigated area, captures the quality and dependability of irrigation and the intensity of cropping in irrigated areas. Cropping intensity, defined as the ratio of gross cropped area to net sown area, is a measure of multiple cropping. Irrigation intensity and cropping intensity have risen over the five decades since 1951-52 as is clear from **Figure 3.3**

Figure 3.3: Cropping and Irrigation Intensity



Source: Agriculture Statistics (2002); http://www.agricoop.com

Irrigation intensity has increased from 1.10 in 1951–52 to 1.37 in 1999–2000 while cropping intensity has increased from a value of 1.11 to 1.34 over the same period, indicating an improvement in multiple cropping in irrigated as well as non-irrigated areas.

3.3.2 Water Conservation and Management Strategies

Over the years, water conservation methods, through an integrated approach to water resources management, have gained currency. The 1980s saw a new trend of revival of traditional technologies and adoption of water management and water conservation technologies aimed at sustainable use of water resources. The Seventh Five Year Plan launched several watershed development programmes, which are a set of technologies aimed at scientific management of water and land. In addition, programmes such as Command Area Development and Water Users' Associations were also launched which aimed at increasing water use efficiency of the major irrigation projects. Several micro- irrigation technologies have also been promoted since the 1980s.

3.3.2.1 Watershed Development Programmes

Several micro-level studies indicate the positive impact of watershed programmes, in terms of increased groundwater storage leading to increase in area under irrigation, increase in cropping intensity, reduction in run-off and soil erosion and overall improvement in the socio-economic status of farmers. A qualitative comparison by Deshpande and Narayanamoorthy (1999) based on the data of 11 States showed that while the impact is of mixed nature across the States, there is improvement in yield, employment, technology adoption and income, along with a shift in cropping patterns towards more remunerative crops. A recent study conducted by P K Joshi et al. (2003) established that the past investments in watershed programmes have yielded the desired results of raising income levels, generating employment and conserving soil and water resources. Joshi has analysed 311 different case studies, evaluating watershed programmes in various agro-ecological regions of the country, and concludes as follows: the mean benefit-cost ratio of the watershed programmes was quite modest at 2.14; the mean internal rate of return (IRR) was about 22 % with a maximum of 94 % (a rate that is quite comparable to any of the successful government programmes); the mean additional annual employment generation in the watershed areas was about 181 man-days per hectare; soil loss of about 0.82 tonnes per ha per year was prevented and additional water storage capacity was created. Augmenting water storage capacity contributed to reducing run-off, expanding irrigated area and increasing cropping intensity. Further, on an average, irrigated area increased by about 34 % and cropping intensity by 64 %. This study also concluded that there exists a positive relationship between people's participation and benefits, with indicators such as benefit-cost ratio, employment, cropping intensity and soil conserved being far ahead in watersheds with high people participation. In addition, identifying appropriate, location-specific technologies for watershed management would contribute to the success of watershed programmes.

3.3.2.2 Drip Irrigation

In India, area under drip method of irrigation has increased from 1500 ha in 1985 to 70,589 ha in 1991–92 and further to 2,46,000 ha in 1997–98. (Raju et al. 2004) Area covered by drip irrigation is the largest in the state of Maharashtra, accounting for half the total area under drip irrigation in the country in 1997–98. Maharashtra recorded 1.2 lakh hectares under drip irrigation in 1997–98 out of 2.4 lakh hectares in the country as a whole. Several organisations have conducted impact studies on drip irrigation and all of them testify to the benefits of drip irrigation by way of substantial water savings and yield increases. The Agriculture Finance Corporation (AFC 1998) made a comprehensive analysis of different water saving technologies practiced by 3900 farmers in selected States and concluded that the adoption of drip irrigation technology by Indian farmers holds the promise of a second Green Revolution. The farmers using drip irrigation methods invariably went for high value horticultural crops and gained a yield increase of 41 % (grapes) to 141 % (pomegranates) over the average State yields. The farmers were also able to recover their investments on drip irrigation within a period of three years.

The results of a study by Indian National Committee on Irrigation and Drainage (INCID) are presented in **Table 3.3**. Similar results have been observed by other studies for sprinkler irrigation, only that it is more suited to close-spaced crops like pulses and cereals.

Table 3.3: Impact of Drip Irrigation on Commonly Adopted Crops

Crops	Water consumption (mm/ha)		Yield (tonnes/ha)		Water Savings (%)	Yield Increase (%)	Benefit-cost ratio	Increase in Water use efficiency (%)
	FMI	DMI	FMI	DMI				
Grapes	532	278	26.4	32.50	48	23	2.32	136
Banana	1,760	970	57.5	87.50	45	52	3.02	176
Citrus	42	8	1.88	2.52	81	35	6.01	289
Pomegranate	1,440	785	55	109	45	98	4.40	167
Sugarcane	2,150	940	128	170	65	33	2.78	204

Note: FMI - Flood Method of Irrigation; DMI - Drip Method of Irrigation
Source: INCID (1994)

The potential for coverage under drip and sprinkler irrigation is estimated to be about 27 mha and 42.5 mha respectively (Ministry of Agriculture 2002). The Task Force on Micro-irrigation (Ministry of Agriculture 2004) has put forth a set of recommendations for the rapid promotion of micro-irrigation by providing a congruence of investment, institutional support, technological interventions, fiscal incentives as well as concession on taxes. If farmers are provided with a total support system — planting material, technical know-how, post harvest handling, marketing — a sizeable part of the irrigated area could be converted to using modern irrigation systems, considerably more area could be brought under irrigation, and water could also be freed up for use by other sectors.

3.3.2.3 Groundwater Recharge

Scientific experiments with artificial recharge using different techniques were started in India between 1976 and 1980. Feasibility studies were carried out on some of the projects using techniques such as induced recharge combined with injection wells, check dams, subsurface dykes and surface spreading. The real breakthrough in artificial recharge occurred between 1995 and 2002, when, with central financial assistance, a number of artificial recharge projects were taken up in rural areas, using a wide spectrum of techniques. The systems varied from place to place, depending upon the hydrogeology and source of water available in a particular area. For instance, an artificial recharge project was undertaken in an intensively irrigated area in the Punjab where the water table was declining. The project was designed to use the monsoon runoff by constructing lateral shafts, vertical shafts and injection wells as recharge structures. These shafts were filled with sand and gravel packs to act as inverted filters so as to provide silt-free water for recharge. Thirty injection wells were constructed between the shafts. The inverted filter and vertical shafts made it possible to have an effective recharge of 4.79 mcm of silt-free water. The direct impact of this project was a rise in the water table of 0.25 m over an area of 30 km^2. The supplement recharge per year amounted to 39 million m^3, able to support 130 additional shallow tubewells. The rise in water level also helped to save pumping energy (26 Mw per year) (Chadha and Kapoor 2000).

3.3.2.4 Conjunctive Use of Water

Conjunctive use is the coordinated management of surface water and groundwater supplies to maximise the yield of the overall water resource. An active form of conjunctive use utilises artificial recharge, where surface water is intentionally percolated or injected into aquifers for later exploitation. Some of the methods for active percolation have already been discussed. A study conducted by Indian Institute of Technology, Roorkee (IIT-R) and the International Water Management Institute (IWMI) in 2002 has shown that irrigation channels can be transformed into recharge systems at minimum cost. The advantage of the canal system can be doubled by using unlined low cost earthen irrigation channels. In addition to providing conveyance of the water for canal irrigation, they also serve as recharging channels and increase the percentage of water percolating into the ground, thus refilling the underlying aquifers. This water is subsequently withdrawn during the post-monsoon season for a second crop. The resulting drawdown of the aquifers maximises the storage potential for the second monsoon and hence prevents waterlogging.

The recharge project by IIT-R–IWMI involved construction of a barrage across the river Ganga at Raolighat which diverts 234 cum / sec of water into the existing Upper Ganga Canal system. The conjunctive use of water by farmers for a period of ten years (1988–1998) has been evaluated to quantify the benefits of this technology. It has been reported that

i) farmers have achieved a 26 % increase in average net income per ha

ii) average depth of groundwater decreased from an average of 12 m below ground level (1988) to 6.5 m (1998)

iii) annual pumping costs savings have been in the region of Rs. 180 million

iv) annual energy savings have been 75.6 million kWh

v) irrigated canal area increased from 1251 ha to 37,108 ha

vi) there has been a 15 % increase in cropped area for rice

vii) canal water input increased from 27 million cum to 643 million cum

In addition there have been additional indirect savings and environmental benefits by avoiding surface water storage structures such as dams. The regions which will be suited for this technology are those with surplus monsoon water and with deep alluvial soils that have good potential to store water, such as the Indo-Gangetic plains.

3.3.2.5 Small Earthen Hand Bunds

The technology of forming a small hand bund of 15-20 cm at about 25-30 cm inside the existing field bund is called *kaivarappu* or *kattuthalai* in Tamil Nadu. By introducing small earthen bunds, the runoff from the field is minimised, thus permitting higher retention time of water and hence lower water consumption. The effect of this technology was tested in the Erode and Salem districts on rice crop under well irrigation. The total water used (irrigation + rainfall) was only 123.5 cm and 124.0 cm in the Erode and Salem districts respectively as against 162.0 cm and 165.0 cm in control. The water use efficiencies (WUEs) were 49.60 kg / ha cm and 48.44 kg / ha cm over control (34.48 kg / ha cm and 33.84 kg / ha cm) respectively in the Erode and Salem districts. The percent increase in grain yield of rice over control was 9.6 and 7.5 respectively for Erode and Salem districts (Palanichamy 2004).

3.3.2.6 Surge Irrigation

A relatively new concept in surface irrigation application method is surge irrigation, which has been introduced and evaluated for field use. Under surge irrigation, water is applied in the field bund intermittently and not on a continuous basis. It increases the advance rate and as a consequence improves water use efficiency. Extensive experiments covering a wide range of long furrow specifications, inflow discharges, cycle ratio and number of surges with different test crops like maize, sunflower, sorghum and groundnut have established the supremacy of surge irrigation over continuous flow. Surge irrigation is estimated to save water by 40 % and increase yield by 25 % (Palanichamy 2004).

3.3.2.7 Treadle Pumps

A treadle pump is a low cost foot-operated pump, simple in design, with two barrels, plungers and pedals, and easily manageable by a single person. It appropriately answers the irrigation needs of small farmers by making them less dependent on the monsoon and raising the cropping intensity. It is ideal for use in regions with high water tables (<25 feet), such as areas of West Bengal, Assam, the coastal areas of Tamil Nadu, and Uttar Pradesh. These are also called *Krishak Bandhu* (farmer's friend) pumps. *Krishak Bandhu* pumps follow the basic lifting principle of the hand pump. The output of the treadle pump is in the range of 0.6 to 0.8 l / sec with a lift of 4.5 m, which is better than any other traditional lifting device. The successful implementation of this technology since 1992 has enabled farmers to grow crops they were not able to grow earlier and has also resulted in significant benefits with an internal rate of return of 100% and a benefit cost ratio of 5 (IDE-India 2000). In West Bengal and Orissa, farmers cultivate ''boro" or winter crops, while in UP and Bihar farmers use treadle pumps for growing vegetables. Farmers using such pumps reap significantly higher results than even diesel pump operators, let alone those without pumps; a drawback of diesel pumps is the leaching away of the fertilisers due to the strong water currents generated.

3.4 Negative Impacts of Irrigation

While the spread of irrigation has resulted in a positive impact on foodgrain production, it has also lead to several social and environmental problems. Irrigation represents an alteration of the natural conditions of the landscape by introducing structures to extract, transport and dispose of water. Dams have displaced people and have destroyed aquatic and terrestrial ecosystems. These consequences are unavoidable if the need for water storage overrides the damages, and benefits-cost ratio becomes high. The negative impacts could be nullified to some extent by awarding compensations and creating alternate ecosystems. There are certain other environmental impacts which result from mismanagement of created resources such as waterlogging, salinity and water pollution from irrigation run-off. Similarly, excessive groundwater withdrawals cause groundwater depletion, land subsidence, aquifer salinisation or accelaration of other types of pollution. In this section, a discussion of negative impacts, particularly those that are not a consequence of irrigation development but that of gross mismanagement of water resources, has been undertaken.

3.4.1 Waterlogging and Salinisation

The operation of irrigation water supply systems can affect the environmental performance of irrigated agriculture. The primary reasons for waterlogging are over- irrigation, lack of conjunctive irrigation, and seepage from canals and irrigation channels. Systems that deliver water continuously or in a fixed schedule are less efficient compared to on-demand water delivery options. The operation and management of irrigation delivery systems must include proper monitoring of seepage and other water losses. An estimate of area affected by waterlogging in the year 1991, provided in **Table 3.4,** shows that the problem of waterlogging is most acute in Haryana, followed by the Punjab. Waterlogging leads to salinity of groundwater and soils. Natural salinity present in water is deposited on the irrigated land after evaporation. Repeated application of saline water renders the soil saline and infertile. In coastal areas soil salinity could also be due to incursion of seawater. Agroclimatic and soil conditions are also responsible for aggravating this problem. An estimate of area affected by water salinity in the year 1991 is also provided in **Table 3.4**.

Table 3.4: Extent of Waterlogging and Salinity in Seven Indian States

State	Area waterlogged ('000 ha)	Area affected by salts ('000 ha)	Percentage area waterlogged	Percentage area salt affected
Bihar	619.70	224.00	3.56	1.29
Gujarat	172.60	911.00	0.88	4.65
Uttar Pradesh	430.00	1,150.00	1.46	3.91
The Punjab	200.00	490.00	3.97	9.73
Haryana	249.00	197.00	5.63	4.46
Rajasthan	179.50	70.00	0.52	0.20
Tamil Nadu	16.19	140.00	0.12	1.08

Source: Government of India (1991 as cited in Kumar 2003)

3.4.2 Groundwater Depletion

Overexploitation of groundwater beyond sustainability limits has been often stated as the negative impact of groundwater irrigation. The Central Groundwater Board (CGWB) publishes data on groundwater utilisation at basin level, State level and district level. State Groundwater Boards document block level statistics on groundwater utilisation. These data offer two estimates: (1) volume of annual groundwater recharge or replenishment and (2) volume of annual groundwater draft or withdrawals. They also have earmarked utilisable irrigation potential, which is 90 % of ultimate irrigation potential, to ensure sustainable development and to maintain base flow for sustenance of river ecology. Overexploitation arises when net groundwater draft for irrigation tends to be in excess of groundwater recharge earmarked for irrigation.

The data reveals that at the national level, groundwater resource is still far from being depleted or overexploited. About 40 % of the groundwater resource (that is, 32.6 million hectare metres) was exploited for irrigation purposes as per 1998 data.

Table 3.5: Groundwater Scenario across States, 1998

State	Utilisable Groundwater for Irrigation	Net Draft for irrigation	Level of Exploitation
	(MhaM/yr)	(MhaM/yr)	(%)
The Punjab	1.47	1.61	109.27
Haryana	0.86	0.72	84.02
Rajasthan	0.95	0.77	80.94
Tamil Nadu	2.02	1.40	69.50
Gujarat	1.56	0.85	54.74
Uttar Pradesh	6.53	3.04	46.61
Maharashtra	2.29	0.88	38.55
Tripura	0.05	0.02	37.18
Bihar	2.57	0.95	36.85
Karnataka	1.24	0.45	36.78
West Bengal	1.77	0.63	35.76
Andhra Pradesh	2.70	0.78	29.00
Kerala	0.59	0.13	21.10
Madhya Pradesh	3.89	0.81	20.93
Himachal Pradesh	0.02	0.00	18.30
Orissa	1.54	0.26	16.91
Goa	0.02	0.00	8.99
Assam	1.72	0.14	8.29
All India	32.63	13.50	41.38

Note: MhaM- million hectare metres

Source: CGWB (2000)

There is wide disparity across States with regard to groundwater utilisation. Groundwater utilised in the Punjab is greater than its annual recharge. Haryana, Rajasthan and Tamil Nadu also have very high levels of groundwater exploitation. All the other States appear to be well below the 100 percent exploitation mark. CGWB has classified the blocks into four categories to describe the level of groundwater development based on the percentage utilisation of groundwater with respect to annual replenishment: overexploited (>100%), critical (90-100%), semi-critical (70-90%), and safe (<70%).

Table 3.6: Block-level Groundwater Exploitation Scenario

S No.	State	1984-85	1992-93	1997-98	2002-03*
1	Andhra Pradesh	0	30	26	197
2	Bihar	14	12	12	20
3	Gujarat	6	26	28	60
4	Haryana	31	51	41	43
5	Karnataka	3	18	16	16
6	Madhya Pradesh	0	3	3	3
7	Maharashtra	-	-	8	34
8	Orissa	-	-	8	0
9	The Punjab	64	70	83	100
10	Rajasthan	21	56	94	166
11	Tamil Nadu	61	97	103	170
12	Uttar Pradesh	53	31	40	22
13	West Bengal	-	-	1	61
14	**Total**	**253 (6%)**	**383 (9%)**	**463 (11%)**	**894(15%)***

Note: Percentage figures in the last row refer to percentage of overexploited and critical blocks in relation to total number of blocks.

* The total number of blocks have been replaced by total number of blocks / taluks / watersheds. Hence we do see the dramatic increase in the number of blocks in the last column but percentage values are comparable.

Source: Ministry of Water Resources (1995, 2000, 2002)

Table 3.6 presents the growth in the number of blocks under critical and overexploited categories i.e., over 90% extraction since 1984–85. Although the number of critical and overexploited blocks represents a small fraction of the total area irrigated with groundwater in India, it does not reduce the magnitude of the challenge. The change in overexploited and critical areas between 1984–85 and 1997–98 represents a 5 percentage point increase. If these rates continue, Dhawan (1995) has estimated that roughly 15 % of the 4248 blocks will be dark or critical by 2020. But CGWB's 2003 Annual Report has estimated that we have already reached the 15 % mark.

Rapid groundwater utilisation has a serious impact not only on the agricultural sector and crop production but also on other sectors such as rural and urban drinking water supplies. Water quality concerns arise as the groundwater table drops into geological formations bearing iron, arsenic, fluoride and other harmful minerals. In addition, declining groundwater tables can have major implications for the base flow of streams as well as volume of stream flow. Unless base flows are maintained, downstream users can lose access to water at critical times and pollution of both surface and groundwater is likely to increase. Changes in volume of stream flow can have major environmental impacts directly affecting surface vegetation, ecologies and wetlands. However, as Dhawan (1995) has pointed out, any evidence on groundwater depletion needs to be viewed with caution since available groundwater reserves estimates are not very accurate and groundwater depletion statistics are not very reliable. In most cases, depletion is a result of localised overexploitation and recurring droughts, which can be corrected if suitable conservation and recharge techniques are adopted.

3.5 Concluding Observations

Technological interventions in the water sector can be grouped into two categories: those aimed at development and utilisation of water resources and those aimed at management and conservation of water resources. The first category of water resources development technologies comprise canal, tubewell, borewell, dug well, tank and other minor irrigation technologies. Canals, tubewells and borewells have enabled large areas of rainfed land to be converted to irrigated lands. The percentage of cultivable area being irrigated has risen from 21 m ha in the early 1950s to 56 m ha in recent years.

The impact of the irrigation development technologies has been manifested in both positive and negative ways. The negative impacts such as waterlogging, salinity and groundwater depletion are a consequence of mismanagement of water resources and lack of holistic planning. In fact, the second category of technological interventions aimed at water management and conservation has been the result of afterthought to mitigate the negative impacts of the former. Again, it is technology which plays a vital role in mitigating or reversing the negative externalities of irrigation development. Conjunctive use, lining of canals, land treatment for drainage and reclamation of saline soils are some of the corrective technologies for waterlogging problems. Rainwater harvesting and groundwater recharge are technologies aimed at tackling groundwater depletion problems. Water demand mitigation by adopting micro-irrigation technologies and on- farm water management strategies have resulted in significant water savings. Watershed programmes also focused on holistic water and soil management of rainfed areas. Several micro-level studies have concluded that all these water management technologies have been very successful. But most of them are very recent and adequate data to quantify their impact on a national level are not available.

This study brings out the role technology has played in shaping the irrigation sector. While government policies have focused on spreading canal, tubewell and borewell technology, they have sidelined traditional irrigation systems such as tanks and dug wells which have been performing equally well in terms of extent of areas irrigated in the 1950s. Particularly, tank irrigation declined from 16 % to about 4 % of net irrigated area over the five decades since 1951–52. Tanks are vital sources of irrigation in the hard rock areas with uneven distribution of rainfall and poor recharge characteristics. Groundwater in these areas has reached dangerously low levels and is unsustainable in the long run. Revival of these traditional irrigation structures and use of technology to enhance their performance are important strategies to be considered in the future.

In the Indo-Gangetic plains with abundant groundwater resources and good recharge characteristics, holistic planning of groundwater development along with adequate recharge structures is essential so that the mistakes of the past are not repeated. In other areas too, judicious planning of groundwater development and recharge using remote sensing and GIS technologies could result in maximum productivity without raising any environmental concerns.

With water resources dwindling and demands surging from all sectors, water conservation by increasing water use efficiency is the only way to go. Technologies such as micro-irrigation and on-farm management need to be promoted among the farmers in a big way. They should also be supported by adequate forward and backward linkages such as credit incentives, industry back up, markets, pricing, etc. Since water saved is water created, more technologies need to be developed for increasing water use efficiency in addition to diffusion of already available technologies.

REFERENCES

AFC. 1998. *Evaluation of Drip Irrigation System*. Mumbai: Agriculture Finance Corporation Limited.

Central Groundwater Board (CGWB). 2003. http://cgwb.gov.in/documents/Annual Report 2002–2003.

Chadha, D.K. and U. Kapoor. 2000. "Rainwater Harvesting and Artificial Recharge — Technological Developments". Paper presented at the National Seminar on Rainwater Harvesting. New Delhi: Central Groundwater Board.

Deshpande, R.S. and A. Narayanamoorthy. 1999. "An Appraisal of Watershed Development Programmes across Regions in India". *Artha Vijnana* 41 (4) 415-15.

Dhawan, B.D. 1982. *Development of Tubewell Irrigation in India.* New Delhi: Agricole Publishing Academy.

_______. 1995. "Magnitude of Groundwater Exploitation." *Economic and Political Weekly*, Vol. 30, 769-75.

IDE-India. 2000. http://www.ide-india.org

Indian National Committee on Irrigation and Drainage (INCID). 1994. *Drip Irrigation in India.* New Delhi.

IWMI-Tata. 2002. "*Innovations in Groundwater Recharge*". Issue 1 Water Policy Briefing. www.iwmi.cgiar.org/waterpolicybriefing/2005

Joshi, P.K., L. Tewari, A.K. Jha and R.L. Shiyani. 2000. "*Meta-Analysis to Assess Impact of Watersheds*". Paper presented at the Workshop on Institutions for Greater Impact of Technologies, National Centre for Agricultural Economics and Policy Research, New Delhi.

Kumar, M.D. 2003. *Food security and sustainable agriculture in India: The water management challenge.* Working Paper 60. Colombo: Sri Lanka: International Water Management Institute.

Ministry of Agriculture, Government of India. 2002. *Horticulture Database.* Gurgaon: National Horticulture Board.

_______. 2004. *Report of the Task Force on Micro-Irrigation.* New Delhi: Department of Agriculture and Cooperation.

Ministry of Water Resources, Government of India, 1995. *Groundwater Resources of India.* Faridabad: Central Groundwater Board (CGWB).

_______. 2000. *Groundwater Statistics.* Faridabad: CGWB

_______. 2002. *Water and Related Statistics.* New Delhi: Central Water Commission.

Palanichamy. 2004 "*Innovative On-farm Water Conservation Technologies.*" Unpublished. Coimbatore: Water Technology Centre, Tamil Nadu Agricultural University.

Planning Commission. *Tenth Five Year Plan, 2002–2007.* New Delhi: Government of India.

Raju, K.V., A Narayanamoorthy, Govind Gopakumar and H.K. Amarnath. 2004. "Water Resources" in *State of the Indian Farmer: a millennium study*. Vol. 3. New Delhi: Academic Foundation.

www.agricoop.nic.in/statistics/sump2.htm

www.agricoop.com. *Agriculture Statistics 2002*.

4 ANIMAL HUSBANDRY*

4.1. Introduction

Since time immemorial, animal husbandry has been closely interlinked with agriculture in India. Livestock are an important source of income and employment in rural areas. Besides complementing and supplementing agriculture, animal husbandry provides security to farmers, especially when agriculture fails. Livestock are essential to millions of poor households across the country not only as a source of income but also as a major source of protein, supplementary nutrition, draught power, fertiliser, fuel and a store of wealth. In the post-Independence period, the Indian livestock sector has undergone a major shift, mainly due to the introduction of new technologies. This chapter discusses the nature of these interventions across the different segments of the livestock sector, namely, dairy and poultry, as well as the impact of these interventions on the production and productivity of livestock products.

4.2. Dairy Sector

4.2.1. Interventions in the Dairy Sector

In pre-Independence India, farmers reared indigenous or native breeds of cattle. Given the relatively low productivity of native breeds, milk production in the country was very low in relation to the huge cattle population present and dairying was confined to traditional pockets in the country. Various projects — technological as well as institutional — have been taken up since 1950 onwards to promote milk production in the country. These initiatives covered the vital spheres of breeding, nutrition and health of milch animals as well as marketing of milk. After Independence, various programmes of dairy development have been taken up, such as the Key Village Scheme (KVS), Intensive Cattle Development Project (ICDP), and Operation Flood (OF).

4.2.1.1 Breeding

The Key Village Scheme, launched in 1951, aimed to develop a sound breeding policy for each State. Under this scheme, superior breed bulls were introduced and artificial insemination using liquid semen was undertaken. The Intensive Cattle Development Project (ICDP) was launched in 1965 to increase milk production through cross-breeding of indigenous breeds with superior breeds of cattle. These initiatives were located both in the breeding tracts of indigenous cattle / buffalo, and also in milk shed areas. Selection among native breeds of cattle was carried out in the former area, and cross-breeding

* Contributed by Dr. K.N. Selvakumar, Professor and Head, Dr.M. Prabu, Assistant Professor, Dr. N. Meganathan, Associate Professor, the Department of Animal Husbandry Economics, Madras Veterinary College, Chennai & Dr A. Serma Saravana Pandian, Chennai.

with germplasm of exotic breeds in the latter area. Though these two programmes, KVS and ICDP, helped in increasing milk production in certain areas of India, they did not have a great impact on increasing milk production in the country as a whole. Only after the implementation of Operation Flood by the National Dairy Development Board (NDDB) at Anand in 1970 did the real spurt in India's milk production begin. Operation Flood was implemented in three phases (1970 to 1981, 1981 to 1985, and 1985 to 1990), and was followed by the Technology Mission on Dairy Development launched by the Government of India in association with NDDB. The main objectives were to establish dairy cooperatives in milk shed areas and to link them to urban consuming centres to create markets for milk produced in rural areas. These dairy cooperatives were based on the Anand pattern of a three-tier system: village-level Milk Producers' Cooperative Societies, district-level Milk Producers' Unions and State-level Milk Federations. These organisations were involved both in supplying quality inputs of feed, fodder, health cover, artificial insemination (AI) with improved germplasm by using frozen semen, as well as in marketing milk in urban areas. Exotic germplasm like Jersey, Holstein and Friesian semen were used in the artificial insemination of local cows. With regard to buffaloes, the focus was on selection of indigenous buffalo breeds and improving them through utilising indigenous improved bulls; Murrah and Surti bulls were used to build up the strain of non-descript buffaloes. Other measures like rinderpest eradication, vaccination against deadly contagious diseases like foot-and-mouth disease (FMD), Black Quarter (BQ), etc., and feed technologies like chemical treatment of straws, urea-molasses mineral blocks (UMMB), bypass proteins, mineral mixtures, pro-biotics, and so on, have also contributed significantly to milk production. AI with improved germplasm by using frozen semen is considered the most strategic intervention in increasing milk production.

Table 4.1: Number of Artificial Inseminations Performed in India

Year	Numbers (in lakhs)
1985-86	83.67
1986-87	92.71
1991-92	159.90
1995-96	181.85
1996-97	188.16
2000-01	217.00
2003-04	247.78

Source: Basic Animal Husbandry Statistics (various years)

The number of artificial inseminations performed in India has increased three-fold since 1985. The number of AI performed as a percentage of total adult female population accounted to about 9 % in 1986–1987 and 17 % in 1996–1997. The technical programme for cross-breeding adopted by the government was to use non-descript cattle as the foundation stock and to impregnate them using semen from exotic breeds. This would produce half-breeds with equal inheritance from the two widely different parents, one contributing endurance and the other the higher productivity.

4.2.1.2 Health

A number of vaccines / antibiotics and diagnostic kits against diseases such as FMD, BQ, haemorrhagic septicaemia (HS) and anthrax have been developed in our country since Independence. Though, production and productivity could be increased by the introduction of foreign germplasm, cross-bred animals are more prone to diseases (especially tropical diseases).

The National Programme on Rinderpest Eradication (NPRE) was put into operation in 1954 with the vaccination programme against rinderpest being started (Randhawa 1986). Between 1954 and 1973, 449.65 million vaccinations against rinderpest were carried out (Shah 1986, 1991). In 1965, a decade after the programme was initiated, there were 306 outbreaks with a loss of 2,214 animals. In 1974, there were 231 outbreaks involving the death of 1,559 animals (Government of India 1976). In 1983–84 deaths due to rinderpest further declined to 687. In 1986–87, 65 million rinderpest vaccinations were done (ibid). Because of the concerted efforts put forth by the government through NPRE, the disease has been eradicated in India.

Another major contagious disease, foot-and-mouth disease, affects high cattle density areas in India. In 1984–85, 60 lakh FMD vaccinations were carried out (Shah 1986). In 1997, the number of outbreaks was 3470 involving 37,557 animals of which 561 died; and this declined to 588 cases, involving 21,998 animals and 227 deaths in 2004. This reduction is due to the effective vaccination programmes initiated by the Government of India (www.oie.int / hs2 / zi_pays.asp?c_pays=88&annee=2004).

Haemorrhagic septicaemia, a bacterial disease, has been the cause of major losses in dairy cattle in India. For the period 1949–53, on an average 1,825 outbreaks occurred in a year involving 11,000 bovines, killing 8,425 of them. An adjuvant vaccine was developed by the Indian Veterinary Research Institute (IVRI) in 1954 which brought down the number of outbreaks by 69 %, the number of animals affected by 89 % and the number of deaths by 80 % for the period 1962–73 (Randhawa 1986). In, 1997, the number of outbreaks had reduced to 1586 involving 13,632 animals of which 4836 had died and this has further reduced to 610 cases involving 3,465 animals and 1672 deaths in 2004 (www.oie.int / hs2 / zi_pays.asp?c_pays=88&annee=2004).

During 1948–52, the bacterial disease Black Quarter affected around 23,525 animals annually, causing 20,230 deaths (86 % mortality). During 1962–73, this disease killed 10,430 cattle and buffaloes. Before the production of vaccines in 1951, it killed on an average 21,500 animals every year (Randhawa 1986). In 2004, the number of outbreaks had decreased to 608 involving 2,282 animals, with 1023 dead. (www.oie.int / hs2 / zi_pays.asp?c_pays=88&annee=2004).

The same trend has been noticed in all other major diseases like anthrax, trypnasomiasis, brucellosis, anaplasmosis, babesiosis, etc. The development of vaccines and diagnostic kits has prevented and reduced the occurrence and spread of disease while antibiotics developed have either cured or lowered the severity of the disease. De-worming and vaccination of animals has been extensively undertaken under several government programmes. On the whole, bovine deaths caused by diseases which numbered over 200,000 over ten years in the 1960s declined to 1,200 in 1980–81 (Shah 1986). Because of such sustained efforts the intensity of contagious diseases has been under control. The country has been declared free of rinderpest since 1996.

In 1950–51, there were 2,000 veterinary dispensaries or hospitals in the country. This figure increased to 16,470 in 1986–87 and 17,820 in 2004 (Basic Animal Husbandry Statistics 2004; Shah 1986).

4.2.1.3 Feed

One of the major constraints in livestock production in our country is the non-availability of quality feed and fodder. Without proper nutrition, cows and buffaloes will not be able to achieve their genetic potential for milk production. The high yielding bovines, especially cross-bred milch animals and buffaloes, need enough cell-wall carbohydrate (fibre) to keep healthy and enough non-fibre carbohydrate (starch and sugar) to provide the glucose precursors needed for producing milk. Good quality green fodder or hay would provide the required fibre. Concentrate mixtures would provide the energy requirements. Oil cakes will provide necessary amino acids for the milk synthesis. It is therefore highly essential to provide a balanced diet to dairy animals to exploit their genetic potential to the maximum extent.

Straws and stover which are deficient in fermentable nitrogen, energy and minerals are staple feeds of ruminants in India as they are the least expensive. Some simple technologies have been developed in the country to improve the quality of feed: chaffing of green fodder and unthreshed straws/stover, soaking of roughage and concentrates, grinding and pelleting that enhances the utilisation of fibrous feedstuffs. To overcome the seasonal deficits in fodder production, methods of conservation and storage of feed resources have also been developed. Urea treatment of straws is one of the most accepted chemical treatments.

The National Dairy Research Institute (NDRI), Karnal, has developed UMMB licks that supply most of the nutrients deficient in straw-based diets. The urea treatment of straw makes it palatable and increases its nitrogen content; in bypass protein technologies, the concentration of undegradable protein is increased up to 65 % in the concentrate; salts of palmitic and stearic acids are used as protected fats and their inclusion increases the energy density of milk and its fat contents (Singh 2001).

Fodder preservation practices such as silage and haymaking are not adopted widely in India because of non-availability of surplus fodder for preservation, though crop residues are stacked for use throughout the year.

4.2.1.4 Marketing

Traditionally, milk production in the country was concentrated only in rural areas and the milk produced was consumed essentially in the local area. Operation Flood, the world's largest co-operative development programme which was launched in 1970 by NDDB, has revolutionised milk production in the country. OF provided a comprehensive package for farmers with regard to breeding, feed and health cover of animals as well as marketing of milk. Artificial insemination was used to augment the productivity of the native breeds.

Box 4.1 Interventions under Different Plans for Dairy Development

First Five Year Plan (1951– 56)

- Establishment of Key Village Schemes (1952)
- 146 key village blocks with AI centres
- Establishment of 650 veterinary hospitals

Second Five Year Plan (1956 – 61)

- Establishment of 196 key village blocks with 670 AI centres
- Establishment of 1900 veterinary hospitals

Third Five Year Plan (1961 – 66)

- 143 government milk supply schemes in big towns
- Establishment of NDDB
- Establishment of a separate department for dairy development in each State

Fourth Five Year Plan (1969 – 74)

- Launch of Operation Flood, phase I
- Establishment of progeny testing scheme – All India Co-ordinated Project on Buffaloes
- Shift of breeding policy from dual purpose cows to cross-bred cows
- Formation of Indian Dairy Corporation

Fifth Five Year Plan (1974 – 79)

- Implementation of Operation Flood, phase II

Sixth Five Year Plan (1980 –85)

- Establishment of frozen semen stations in different States

Seventh Five Year Plan (1985 – 90)

- Implementation of Operation Flood, phase III

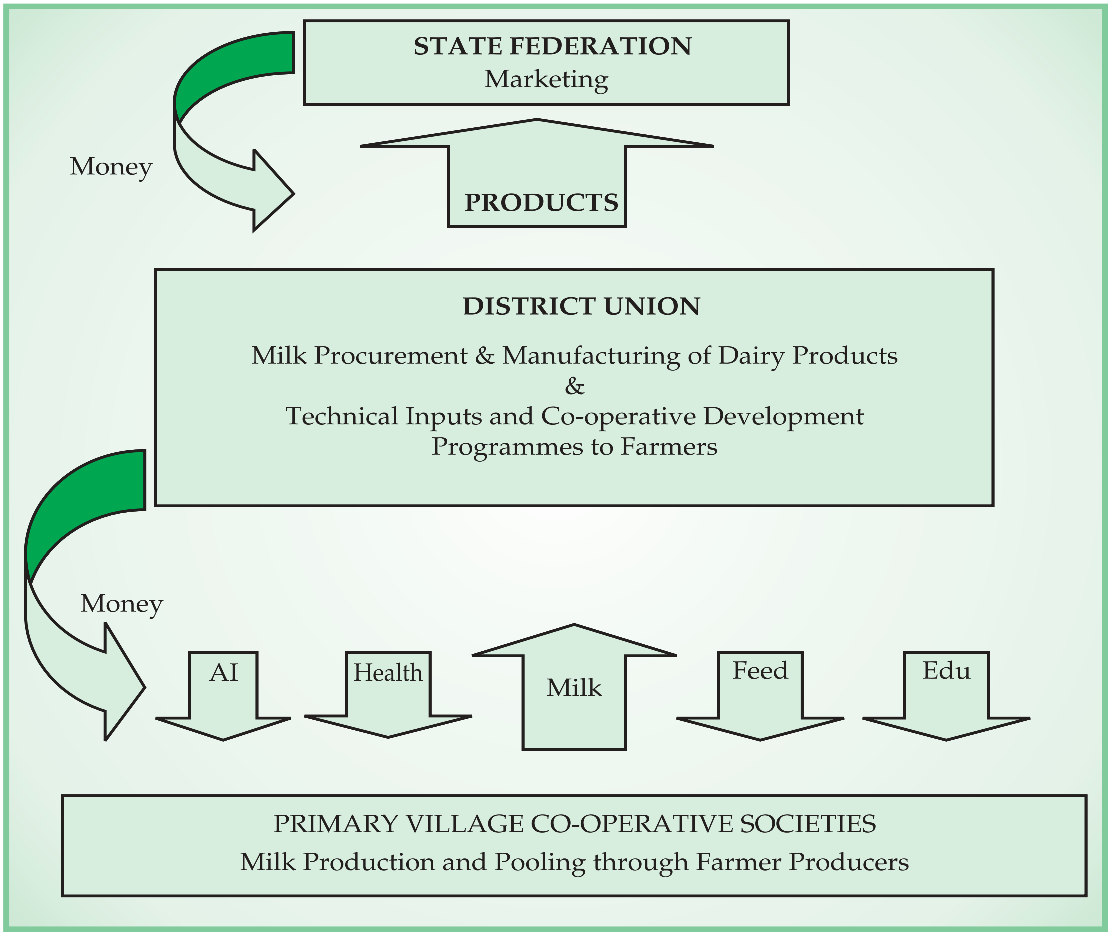
Tenth Five Year Plan (2002 – 07)

- Conservation of threatened indigenous breeds

Note: No major dairy development programmes were launched during the Eighth and Ninth Plan periods

Fodder development was given importance and fodder seedlings were supplied to farmers; medicines and vaccines were provided at the farmers' doorsteps; and more importantly, markets for rural milk were created through the co-operative set up. **Figure 4.1** describes the three-tier Anand pattern.

Figure 4.1: Anand Pattern



Source: Personal Communication, PRO, Anand Milk Union Limited (AMUL), Anand

The first phase of Operation Flood was launched in 1970. The programme involved organising dairy cooperatives at the village level, creating the physical and institutional infrastructure for milk procurement, processing, marketing and production enhancement services at the union level, and establishing dairies in India's major metropolitan centres. The main thrust was to set up dairy cooperatives in India's best milk sheds — around 39 milk shed areas of the country — and linking them with the cities of Mumbai, Kolkata, Delhi and Chennai. Phase II of the project, implemented during 1981–85, raised the milk-shed areas from 39 to 136 and was linked to over 290 urban markets. A self-sustaining system of 43,000 village cooperatives covering 4.25 million milk producers came into being by 1985. The third phase of Operation Flood, undertaken from 1987 to 1996, aimed at consolidating the gains of the earlier phases. The main focus of the programme was on achieving financial viability of the milk unions / State federations and adopting the salient institutional characteristics of the AMUL Pattern or AMUL Model Cooperatives. At the conclusion of the third phase of Operation Flood in 1996, 72,744 district cooperative societies in 170 milk sheds of the country, with a total membership of over 9 million, had been organised. Phase III gave increased emphasis to research and development in animal health and animal nutrition. Innovations like vaccine for theileriosis, bypass protein feed and urea-molasses mineral blocks, all contributed to the enhanced productivity of milch animals.

Table 4.2: Achievements of Operation Flood, India, 1970-1996

Features	Achievements under Operation Flood		
	Phase I	Phase II	Phase III
Village cooperatives set up (thousands)	13.30	34.50	72.50
Members (lakhs)	17.50	36.30	92.63
Milk sheds covered	39.00	136.00	170.00
Village DCS set up ('000s)	13.30	34.50	72.50
Average milk procurement (mkgpd)	2.56	5.78	10.99
Liquid milk marketing (llpd)	27.90	50.10	100.20
AI centres ('000s)	4.90	7.50	16.80
AI done (lakhs / year)	8.20	13.30	39.40

Note 1: mkgpd: million kg per day; llpd:lakh litres per day;.MTPD-metric tonnes per day.

2: Starting and Conclusion days of Phases I, II & III are 1 July 1970 to 31 March 1981; 2 October 1979 to 31 March 1985 and 1 April 1987 to 31 March 1996, respectively.

Source: Gupta (1997); NDDB (1996)

4.2.1.5 Institutional Interventions[2]

Various Central and State livestock research institutions in India like IVRI, NDRI, State agricultural / veterinary universities and national-level bodies like NDDB and National Bank of Agriculture and Rural Development (NABARD) have taken important initiatives in developing technologies in different areas.

The National Dairy Development Board started functioning with effect from 1965, with the major objective to promote, plan and organise programmes for dairy development. It launched the Dairy Herd Improvement Programme Action (DIPA) to achieve genetic changes in selected cattle and buffalo population. The Open Nucleus Breeding System (ONBS) of NDDB, which evaluates the quality of bulls and technology for the commercial production of urea- molasses blocks, has been transferred to various milk unions (www.nddb.org.). Indian Immunologicals Ltd. (IIL) was set up by NDDB in 1983 with the objective of making available the FMD vaccine to farmers at an affordable price. Following the successful introduction of vaccine *Raksha*, IIL launched a tissue culture vaccine, *Raksharab*, in 1989. This was the first Indian tissue culture vaccine in the market. Subsequently IIL has developed many biologicals through its own R&D efforts and has launched several vaccines in the Indian market at affordable prices.

[2] This section is based on discussions with experts in the field as well as on a survey of literature. We are grateful to several eminent scientists who have been kind enough to give us their valuable time. We would particularly like to thank Dr. R. Kadirvel and Dr. N. Balaraman, former and present Vice Chancellors, TANUVAS. We have drawn heavily from the following sources: Randhawa (1986) and Shah (1986)

Table 4.3: Significant Achievements of Indian Immunologicals Ltd.

1983	Foot-and-Mouth Disease vaccine plant commissioned
1989	First Indian company to manufacture tissue veterinary rabies vaccine
1989	Tropical theileriosis vaccine for cattle, first of its kind in the world
1992	Rinderpest, HS and BQ vaccines
1996	Introduction of enterotoxaemia vaccine
1998	FMD - Ovac (FMD adjuvant vaccine) introduced
2000	World's first combination vaccine for FMD, HS and BQ - Raksha Triovac

Source: www.nddb.org/institutions/ind-immu-ltd.html

The National Dairy Research Institute was earlier called the Imperial Institute for Animal Husbandry and Dairying, and was established during the colonial period in Bangalore in 1923. The institute undertakes basic and applied research in the areas of dairying with the objective of developing dairy farming systems for different agro-climatic conditions. It has been responsible for the development of two high milk producing strains of cattle, Karan Fries and Karan Swiss, and also the world's first buffalo calf, Pratham, born through *in vitro* maturation and *in vitro* fertilisation of buffalo oocytes[3] developed at NDRI in the year 1990 (www.karnal.nic.in/res_ndri.asp).

The Indian Veterinary Research Institute, the first research laboratory of the country in veterinary and animal sciences, was established in 1889 as the Imperial Bacteriological Laboratory at Pune. The objectives of the institute are to conduct research, to provide post-graduate education and transfer technology in the areas of animal health and production, and to act as a national referral centre for veterinary cultures, disease diagnosis, biologicals and immuno-diagnostics. The institute has developed a large number of immunobiologicals against viral, bacterial and parasitic diseases including tuberculin PPD, as also a number of vaccines diagnostic kits (www.ivri.nic.in).

Various state agricultural/veterinary universities have also played a vital role in the development of breeding techniques, vaccines, diagnostic kits and dissemination of modern scientific knowledge at the regional level.

National Bank of Agriculture and Rural Development, started in 1982, also plays a vital role in dairy development by financing various dairy projects through State-level institutions, nationalised banks, co-operative banks and rural banks.

4.2.2 Impact of Technological and Institutional Interventions

The various technological and institutional measures taken to develop the dairy sector have had a direct impact on the productivity of milch animals and production of milk as well as the per capita availability of milk in the country. This section attempts to elaborate the positive impact of interventions.

[3] A cell from which an egg or ovum develops by meiosis; a female gametocyte. It is a female gametocyte or germ cell involved in reproduction (www.thefreedictionary.com/Oocytes).

From **Figure 4.2** it is clear that milk production in India, after stagnating around 20 million tonnes for about 20 years between 1950 and 1970, registered a rise from the early 1970s, crossing 30 million tonnes by 1980–81, 50 million tonnes by 1990–91 and 90 million tonnes by 2004–05.

Figure 4.2: Milk Production

Source: Basic Animal Husbandry Statistics (Various years)

During the 1970s (1970–71 to 1980–81), when OF was initiated, milk production grew at an annual compound growth rate of 3.69 %. In the 1980s the rate of growth of milk production further increased and was 5.48 %. In the 1990s, while milk production grew at a high and positive rate of 4.11 % per annum, there was a decline in the rate of increase in milk production compared to the earlier decade.

Table 4.4: Milk Production, India

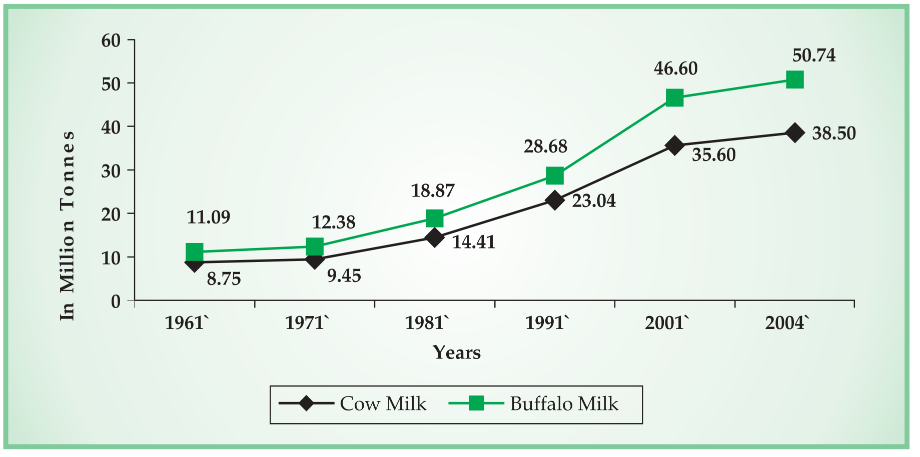
(million tonnes)

Year	Milk Production			
	Cow Milk	Buffalo Milk	Goat Milk	Total Milk
1961	8.75	11.08	0.53	20.37
1966	6.91	11.87	0.57	19.36
1971	9.45	12.37	0.67	22.50
1976	11.46	15.01	0.81	27.30
1981	14.40	18.86	1.02	34.30
1986	18.50	26.23	1.36	46.10
1991	23.03	28.67	2.34	54.06
1996	26.83	36.99	3.01	66.84
2001	35.60	46.60	2.60	84.80
2004	38.50	50.74	2.76	91.00

Source: www.faostat.fao.org

Milk production comprises of milk from cows, buffaloes and goats.[4] Over the period 1961 to 2004, the rate of increase in milk production from cows as well as buffaloes has remained very similar all through the four decades. This has meant that the importance of cow milk or buffalo milk in total milk production has remained more or less constant over the years: while cow milk accounts for 40 to 42 % of total milk production, buffalo milk is in the range of 53 to 55 % and goat milk accounts for 2 to 4 %.

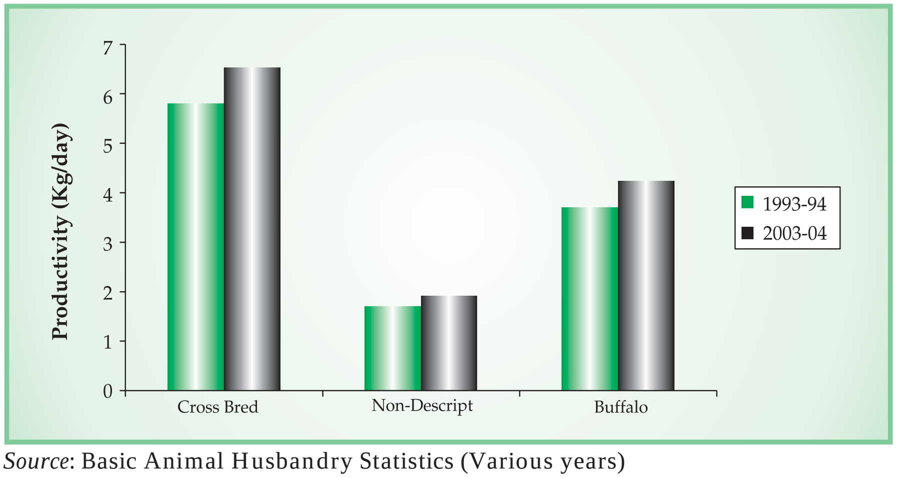
Figure 4.3: Composition of Milk Production



Source: www.faostat.fao.org

On the basis of data provided in *Basic Animal Husbandry Statistics*, it is clear that over the years the contribution from cross-bred cows has increased. In 1993–94 cross-bred cows contributed 16 % and non-descript cows contributed 28 % to total milk production, while in 2003–04 the corresponding figures were 19 % and 23 % respectively. Data provided in **Figure 4.4** further indicates that in 1993–94 as well as in 2003–04, the productivity of cross-bred cows was nearly three-and-a-half times higher than that of non-descript cows and one-and-a-half times higher than that of buffaloes. Given the high productivity of cross-bred cows, the increase in milk production is certainly related to the adoption of cross-breeding technology combined with measures taken to improve the nutrition and health of milch animals.

Figure 4.4: Average Productivity of Milch Bovines



Source: Basic Animal Husbandry Statistics (Various years)

[4] Data on milk production as well as the composition of milk production in India is available in the Basic Animal Husbandry Statistics published by the Ministry of Agriculture, and the FAO website. Figure 4.2 (using the former source) and Table 4.4 (using the latter source) show a discrepancy in the data provided by them. However, the broad trend in milk production as given by both these sources does not vary.

In 1982, the percentage of cross-bred cattle in total cattle population was of the order of 4.5 %. However, this percentage increased gradually and by 2003, 13.3 % of total cattle were cross-bred. Considering only milch cows, around 10 % were cross-bred in 1992 while this increased to 14 % by 1997 (Basic Animal Husbandry Statistics various years).

Increase in milk production in the country is largely related to the increase in productivity of milch animals. From **Table 4.5** and **Table 4.6** it is clear that while female bovine population has been increasing over the years, the rate of increase in population is much lower than that of milk production across the five decades under consideration.[5] While milk production has grown at an annual compound growth rate of over 3 %, female bovine population has grown at less than 1 % (Table 4.6).

Table 4.5: Adult Cattle and Buffalo Population, India , 1951 to 1997

(in millions)

Year	Adult Female Cattle	Adult Female Buffalo	Total Adult Female Bovines
1951	54.40	21.00	75.40
1961	51.00	24.30	75.30
1972	53.40	28.60	82.00
1982	59.21	32.50	91.71
1992	64.36	43.81	108.17
1997	64.42	46.77	111.19

Source: Livestock Census in Basic Animal Husbandry Statistics (various years)

Table 4.6: Rate of Growth of Milk Production and Female Bovines, 1951-2001

Annual compound growth rate of milk production		Annual compound growth rate of adult female bovines	
Period	**Percentage**	**Period**	**Percentage**
1950-51 to 1960-61	1.64	1951-1961	0.01
1960-61 to 1970-71	0.96	1961-1972	0.78
1970-71 to 1980-81	3.69	1972-1982	1.16
1980-81 to 1990-91	5.48	1982-1992	1.63
1990-91 to 2000-01	4.11	1992-1997	0.55
1950-51 to 2000-01	3.16	1951-1997	0.85

Source: Table 4.5 and Figure 4.2

In order to understand the importance of yield increase (of milch animals) in increasing milk production in the country, a crude exercise has been attempted using data provided by the FAO.[6] The average yield of milk per cow over the period 1961 to 1970 was 437.8 kg per annum and that of buffalo was

[5] In the absence of time series data on milch animals, we have used total female bovine population.

[6] This exercise gives a broad idea of gain in milk production due to yield increases. However, it is important to note that number of adult female bovines rather than number of milch animals is used in the calculation.

898.1 kg per annum. Assuming the average yield to remain constant at this level, milk production for the years 1961 to 2001 has been estimated as a product of this average yield and the actual number of adult female cattle and buffalo. The sum of estimated cow milk production and estimated buffalo milk production provides the total estimated milk production for the years 1961 to 2001. Comparing the estimated series of milk production with actual milk production in the country, an estimate of gain due to productivity increase has been calculated. As can be seen from **Table 4.7**, milk production would have remained at less than 45 million tonnes in 2001 if there had been no improvement in the yield of milch animals.

Table 4.7: An Estimate of Gain in Milk Production

(in million tonnes)

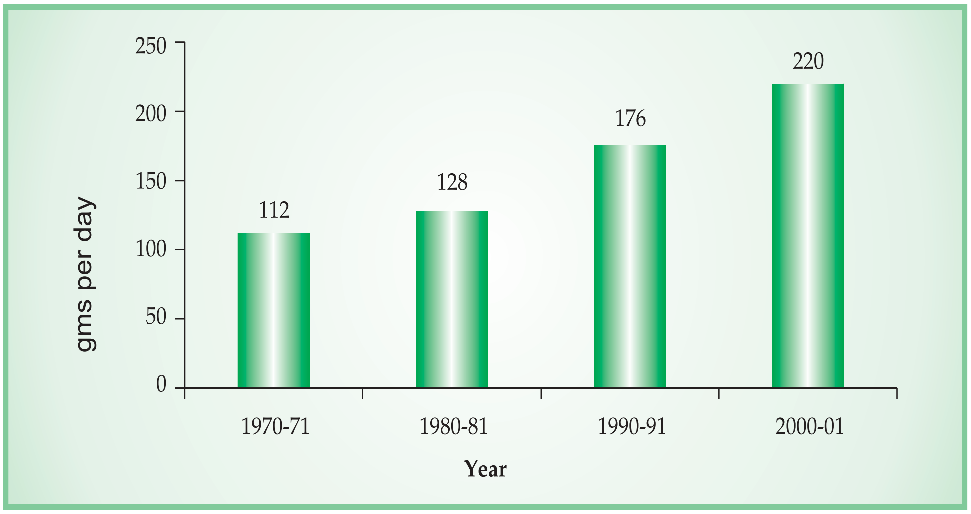
Year	Actual milk production	Estimated milk production	Estimated gain in milk production
1961	19.84	20.24	-0.40
1971	21.83	22.18	-0.36
1981	33.27	28.14	5.13
1991	51.71	36.70	15.01
2001	82.20	44.76	37.44

Note: Milk production refers to cow and buffalo milk

Source: www.faostat.fao.org

The rapid increase in milk production has resulted in a rise in per capita availability of milk in the country from 112 gm / day in 1971 to 220 gm / day in 2001. In 2005, it further increased to 232 gm / day.

Figure 4.5: Per Capita Availability of Milk



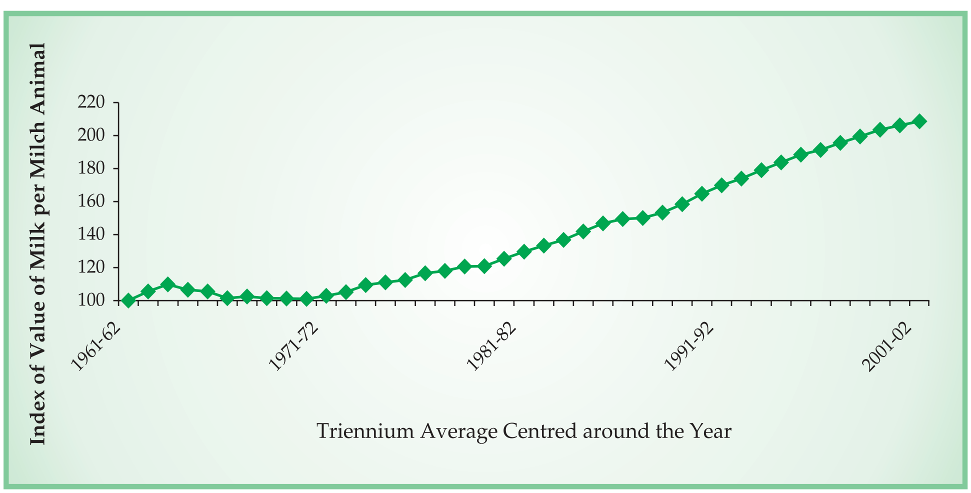
Source: Basic Animal Husbandry Statistics (2004)

A review of literature brings out evidences of the advantage of cross-breeding technology. Lalwani (1989), while estimating technological change in the dairy farming sector in India from the input-output data for the reference period 1979–80 (collected under the Operation Research Project of NDRI by applying the Cobb-Douglas production function), has found that adoption of cross-bred cattle in place of buffaloes or indigenous cows led to higher milk yield / day. Gaddi and Kunnal (1996) have studied the sources of output growth in the new milk production technology (cross-breeding) in Karnataka by following the Cobb-Douglas production function. The results indicated that the total growth in milk yield per cow per lactation by shifting to cross-bred animal was about 146 %. The estimated growth in milk output was 146 %, of which 47 % was contributed by technology. Further, Kumar and Pandey (1999) have also estimated that livestock output in India grew at 2.59 % per annum over 1950–51 to 1995–96. They had used the total factor productivity approach for analysing the sources of growth in the livestock sector. According to their estimate, technical change contributed about 30 % to overall output growth over 45 years.

4.2.3 Technology Achievement Index — Dairy Sector

As in the crop sector, in the dairy sector too, the impact of technological interventions has been estimated using the value of output per milch animal at constant prices. Using the time series of value of milk (provided by the National Accounts Statistics of India, at constant prices) and a time series of estimated number of milch animals (on the basis of FAO data), the value of milk output per milch animal has been calculated at 1993–94 prices, for the period 1960–61 to 2002–03. A simple index has then been derived, by using the triennium value of 1960–61 to 1962–63 as the base value. The value for the base period, Rs.4110, has been equated to 100; the value improved to Rs.5325 with an index value of 130 by 1981–82 and increased rapidly to Rs.8570 with an index value of 209 in 2001–02. Given that the value of output per animal, expressed in constant terms, reflects the yield per animal, it has been considered an appropriate indicator to measure the technology achievement in the dairy sector. The technology achievement index has increased slowly over 1970 to 1980 and has increased rapidly since then.

Figure 4.6: Technology Achievement Index - Dairy Sector



Source: Table 4.8

Table 4.8: Technology Achievement Index, Dairy Sector

Triennium average centred around the year	Value of milk output per milch animal in Rs. (1993-94 prices)	Technology Achievement Index
1961-62	4110	100
1971-72	4227	103
1981-82	5325	130
1991-92	6977	170
2001-02	8570	209

Note: It has not been possible to estimate TAI from 1950-51 as data on milch animals could be estimated only from 1960-61 onwards.

Source: EPW Research Foundation (2004); www.faostat.fao.org

4.3 Poultry sector

4.3.1 Interventions in the Poultry Sector

Systematic efforts to develop the poultry industry on scientific lines began in post- Independent India. The poultry sector has evolved from a backyard activity to a vertically integrated and organised sector since the 1970s. While superior exotic poultry breeds with high egg productivity were introduced from time to time to improve the indigenous stock in the country, such efforts proved infructuous in the absence of a systematic large-scale development programme (Jain 1991).

Commercial poultry farming began under the First Five Year Plan (1951–55) with the establishment of 33 extension centres for providing improved breeds — the imported pure-bred varieties such as White Leghorn and Rhode Island Red — and upgrading indigenous poultry stocks. Pilot poultry extension centres were established during the later half of the First Plan. The Second Five Year Plan gave further impetus to backyard poultry farming in rural areas and commercial farming in urban areas. Pure bred exotic stocks, including 30,000 White Leghorn and Rhode Island Red chicks, were received along with poultry farming equipment early in 1957 from the USA, under the Technical Co-operation Mission (TCM). From 1959–65, large regional poultry farms were set up in 5 urban centres across the country, for the multiplication and distribution of quality stock for extension purposes. However, even by the end of the Second Plan period, commercial poultry farming did not take root and backyard poultry units predominated in rural areas (Jain 1986, 1991). In the Third Five Year Plan, the Government of India helped to establish 5 large franchise hatcheries in the private sector.[7] This new concept in poultry development was successfully tried out under the Intensive Poultry Development Project (IPDP). Under the Freedom from Hunger Campaign, about 10,000 pure-line chicks were imported from Australia in 1965 to popularise high-laying stocks in government breeding farms. Some private entrepreneurs in the country set up franchise hatcheries in collaboration with foreign based poultry breeding farms. Introduction of deep litter and cage systems of poultry keeping, multiplication of exotic and high yielding

[7] Franchise hatcheries purchase parent stocks usually from secondary breeders, raise these parents and produce and sell the commercial chicks to the farmers. The secondary breeders have the grandparent stocks of exotic germplasm.

layers in public and private sectors, and mass preventive vaccination against common poultry diseases were initiated in this period. The import of poultry stocks in the form of grandparental lines has continually expanded since the early 1960s and towards the end of the 1970s as many as 10 franchise hatcheries of international fame were operating in the country. The Government of India took a major policy decision in 1976 to greatly restrict the further import of poultry stocks. Another regulation in 1980 almost completely banned the import of the grandparental lines, but permitted the import of pure-line stocks for further breeding in the country.

During the Fourth Plan period, the All India Coordinated Research Project on Poultry Breeding (AICRP) was initiated in 1970 by ICAR to produce superior genetic stocks of layers and broilers to achieve self-reliance in poultry production. The Project was initially operated with a coordinating unit located at IVRI till 1979. The coordinating unit of AICRP was subsequently upgraded to the status of a Project Directorate during the last part of the Seventh Plan period, and was renamed as the Project Directorate on Poultry (PDP) and was established at Hyderabad in 1988. It carries out applied and technology generating research on chicken and also acts as the repository for two random-bred control populations (one each for layer and broiler chicken). It maintains a Germplasm Centre to make available improved strains and stocks to the various user agencies. PDP has developed layer cross *Krishilayer*, producing 270 eggs in 72 weeks, and broiler cross *Krishibro*, attaining a weight of 1500g at 6 weeks of age**.** Layer crosses, viz., *ILI-80*, *ILM-90* and *ILR-90*, with egg-laying capacity of 280-290 eggs of standard size egg weight, have been evolved and released under AICRP for commercial exploitation. Similarly, broiler crosses, viz., *B-77*, *IBL-80*, *IBB-83* and *IBI-91* with the potential to attain above 1500g body weight at 6 weeks of age, have been evolved and released for commercial exploitation. In addition, dual purpose crosses, viz., *Vanaraja* and *Gramapriya*, have been developed for rural backyard poultry production (www.pdonpoultry.org / history.html).

Among the public sector research institutions, the Indian Council of Agricultural Research (comprising the Indian Veterinary Research Institute, Izatnagar, Central Avian Research Institute (CARI), Izatnagar, and Project Directorate on Poultry, Hyderabad) plays an important role in poultry research. IVRI undertakes basic, applied and adaptive research in all disciplines relating to avian production, post-harvest technology, development, conservation and maintenance of poultry germ-plasm, and provision of post-graduate education and training in poultry science.

Box 4.2 Technological Interventions under Different Five Year Plans for Poultry Development

First Five Year Plan (1951 – 56)

- Pilot project to establish 50 extension centres under the Indo-US Technical Cooperation programme

Second Five Year Plan (1956 – 61)

- Establishment of five regional farms with 269 poultry extension centres

Third Five Year Plan (1961 – 66)

- Development of deep litter system, multiplication of exotic breeds and organisation of inter-State poultry development projects

Fourth Five Year Plan (1969 – 74)

- Establishment of 28 intensive egg and poultry production-cum-marketing centres and 19 new farms started

Fifth Five Year Plan (1974 – 79)

- Establishment of 3 central and regional poultry breeding farms, 3 random sample laying test units, 61 intensive poultry production-cum-marketing centres
- Initiation of special poultry production programmes

Sixth Five Year Plan (1980 –85)

- ICAR-evolved layer strain ILI 80 and fast growing broiler strains IBK 80 and IBB 80
- National Hatchery Registration programme
- Establishment of National Egg Coordination Committee (NECC)

Seventh Five Year Plan (1985 – 90)

- Development of infrastructure facilities

Tenth Plan (2002 – 07)

- Scheme for the development of rural back yard poultry production
- Assistance to State poultry farms

Note: No major poultry development programmes were launched during the Eighth and Ninth Plan periods.

More than 90 % of the commercial layers and broilers in the market today are crosses, strain crosses, breed crosses and inbred hybrids.[8] Crossing results in improved performance in the progeny. For the production of commercial crosses, one line is used as male line (sire line) and the other as female line (dam line). When a commercial chick is a single cross, each line entering into the cross is called a parent line. When four lines are used, each line is called a grandparent line. The main attributes of a commercial layer are high egg production, low body size, less feed consumption, optimum egg size etc.; that of a commercial broiler are high juvenile body weight especially at the marketing age, better feed efficiency and low brooder house mortality.

[8] Hybrids chicks are produced by a special kind of strain or breed crossing in which the parent strains are purposively inbred for two or more generations. Commercial hybrid chicks usually have 3 or 4 such inbred strains as grandparents.

Introduction of high-yielding varieties of eggers — Rhode Island Red, White LegHorn, Babcock, etc. — during the 1970s and broilers — Cobb, Ross, etc. — in the 1980s was a benchmark in the development of the poultry sector in India. In a significant research breakthrough, ICAR has successfully developed indigenous vaccine against the bird flu disease in 2006[9] (www.dahd.nic.in).

In India, strain cross or inbred hybrids of White Leghorn origin are used for the production of white-shelled eggs, while cross-breeding of White or Red Cornish, White Rock and New Hampshire breeds is undertaken in the production of commercial broilers.

ICAR has established a pure-line multiplication centre at PDP. A germplasm centre for maintenance and improvement of elite layers and broilers has also been established here, besides the maintenance multiplication of central control population units for egg and meat (Narayankhedkar 2003). Other than the ICAR institutes, agricultural/veterinary universities as well as central poultry breeding farms in Mumbai, Bangalore, Bhubaneshwar and Chandigarh, random sample poultry performance testing centres in Bangalore, Bhubaneshwar, Mumbai and Gurgaon, and regional feed analytical laboratories in Bhubaneshwar, Mumbai and Chandigarh, are working in various spheres of poultry development in India. Also involved in poultry development are the Central Food and Technical Research Institute, Mysore, and the Council of Scientific and Industrial Research.

Table 4.9: Genetically Superior Germplasm Developed by Public Research Institutions, India

Name of Commercial Stock	Type of Stock	Name of the Institute
ILI 80 (white egger)	Commercial layers	CARI, Izatnagar
ILM 90 (white egger)	Commercial layers	Kerala Agricultural University, Mannuthy
ILR 90 (white egger)	Commercial layers	Andhra Pradesh Agricultural University, Hyderabad
Krishilayer	Commercial layers	PDP, Hyderabad
Krishibro	Commercial broilers	PDP, Hyderabad
HH 260 (white egger)	Commercial layers	Central Poultry Breeding Farm (CPBF), Bangalore
BH 78 (white egger)	Commercial layers	CPBF, Bombay
Kalinga Brown (brown egger)	Commercial layers	CPBF, Bhubaneshwar
CARI Gold 92 (brown egger)	Commercial layers	CARI, Izatnagar
CARI Rainbro (B 77) (coloured plumage)	Commercial broilers	CARI, Izatnagar
IBL 80 (coloured plumage)	Commercial broilers	Punjab Agricultural University, Ludhiana
IBB 83 (coloured plumage)	Commercial broilers	University of Agricultural Sciences, Bangalore
HH-260	Commercial layers	CPBF, Bangalore
CARIBRO Vishal 91(white plumage)	Commercial broilers	CARI, Izatnagar
CARIBRO Rangeela (multicoloured plumage)	Commercial broilers	CARI, Izatnagar
CARIBRO Mritunjai (naked Neck)	Commercial broilers	CARI, Izatnagar

Source: Singh et al (2002)

[9] The outbreak of bird flu (known as avian influenza) in India in February 2006 affected the poultry industry adversely.

Apart from the public sector, the private sector is also engaged in research on poultry. The Venkateshwara Hatcheries Group was established by Dr. B.V. Rao in 1971, as a franchise of Babcock Poultry Farm, Ithaca, NY. Kegg Farms, India Poultry Farm, and Deejay Hatcheries are some of the other private hatcheries that have established a nation- wide network of franchise hatcheries in the country.

Along with the introduction of high-yielding layers and broilers, vaccines and medicines have been developed against diseases such as infectious bursal disease, Newcastle disease, fowl pox, fowl cholera and coccidiosis. Management practices such as the deep litter system and the cage system, and scientific feeding with automatic feeders and waterers have also been introduced. Over the years, there has been a definite decline in the incidence of diseases due to the adoption of vaccines and medicines. Infectious bursal disease (Gumboro disease) recorded 447 outbreaks involving 1,89,927 birds and the death of 45,939 birds in 1996. In 2004, the incidence declined to 167 outbreaks involving 34,440 birds, with 6,584 birds dying. In 1996, 532 outbreaks of Newcastle disease were reported, involving 1,52,004 birds and 25,438 deaths. In, 2004, outbreaks of Newcastle disease were 323, involving 79,590 birds and 10,742 deaths. Fowl pox was the cause of the death of 1,487 birds (315 outbreaks involving 16,290 birds) in 1996; this declined to 170 deaths (130 outbreaks involving 3,971 birds) in 2004. In the case of fowl cholera, 394 deaths were reported (89 outbreaks involving 5,554 birds) in 1996 and in 2004, the death rate was 419 birds in spite of a significant increase in the poultry population (8 outbreaks involving 722 birds). Coccidiosis, another major disease that affects birds, has also been controlled because of the development of a new range of antibiotics. In 1996, 4,123 deaths were reported (130 outbreaks involving 1,05,976 birds) and in 2004, while there were 147 outbreaks involving 23,559 birds, the mortality rate declined to 3,160 (www.oie.int / hs2 / zi_pays.asp?c_pays=88&annee=2004 and 1996).

As regards poultry feed, when birds were reared on free ranges, grains and millets constituted their diet. When commercial poultry farming came into existence, birds were reared in enclosed houses or sheds and the feed formulation was a mixture of multiple ingredients such as maize, wheat, rice, rice bran, de-oiled rice bran, fish meal, meat meal, and bone meal (Sadana 2004). Some of the technological innovations in poultry feed which are worth mentioning are the use of agro-industrial by-products such as de-oiled rice polish, alternative protein sources like meat meal and Lucerne meal, use of by-products and wastes, probiotics (growth promoters and feed savers), antibiotic feed additives and feed grade enzymes, as also feed processing technologies like pellet feeding, crumbled feeds, etc. (ibid).

In the sphere of marketing of eggs, the major intervention has been the establishment of the National Egg Coordination Committee (NECC), in the year 1982. NECC was established as a registered trust comprising of poultry farmers as well as egg traders. The major objective of NECC is to fix a price that ensures a fair return to the farmers as well as decent margins to the middleman. NECC also undertakes egg promotion campaigns, export promotion, market intervention, and development of rural marketing / distribution channels for eggs (www.e2necc.com / necc-beginning.html).

4.3.2 Impact of Interventions in the Poultry Sector

4.3.2.1 Egg Production

Egg production in the country has registered a 25-fold increase, from 1.8 billion eggs to 45 billion eggs, over 1950–51 to 2004–05. India, with an output of 45 billion eggs in 2004–05, ranks among the top six egg-producing countries in the world. The per capita availability of eggs has also witnessed an impressive growth, from 5 eggs / person / annum in 1950–51 to 45 eggs / person / annum in 2004–05.

Table 4.10: Egg Production and Per capita Availability, India

Year	Eggs (in millions)	(Per person/annum)
1950-51	1832 (100)	5
1960-61	2881 (157)	7
1973-74	7755 (423)	14
1980-81	10060 (549)	15
1990-91	21101 (1152)	25
2000-01	36632 (2000)	36
2004-05	45200 (2467)	45

Note: Figures in brackets provide the index with respect to 1950-51.
Source: Basic Animal Husbandry Statistics (2004); www. dahd.nic.in

Analysing the growth pattern of egg production in the country over time, it is clear that the initial spurt in production came about in the 1960s, the period when exotic and high-yielding layers were introduced and various other efforts were taken to promote commercial poultry farming. Egg production over 1960–61 to 1973–74 increased at an annual compound growth rate of 7.91 %. The second spurt in production was during the 1980s, when commercial poultry farming flourished in the country. Egg production during the 1980s grew at an annual compound growth rate of over 7.6 %. During the 1990s, while there was a decline in the rate of growth compared to the earlier decade, the growth remained at a high level of over 5 % per annum.

The share of *desi* eggs (eggs of country or *desi* fowl) and improved fowl in the total egg production statistics is shown in **Figure 4.7**. The compositional change in egg production indicates that the share of improved fowl in total egg production has increased over the years: in 1993–94, 66 % of total egg production was from improved fowls while this percentage increased to 78 % in 2003–04. This pattern is because of the increased productivity of improved fowl. On an average, while country fowl yield was 104 eggs / annum, the productivity of improved fowl was 254 eggs / annum in 2003–04.

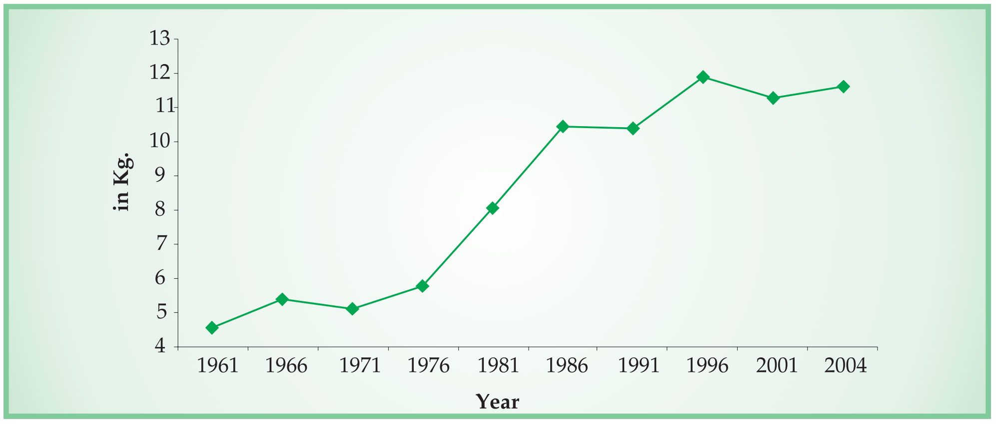
Figure 4.7: Compositional Change in Egg Production

Source: Basic Animal Husbandry Statistics (various Years)

Increase in egg production in the country was brought about by an increase in the number of hybrid layers as well as an improvement in their productivity. The average productivity of improved layers in

1993–94 was 232 eggs / annum and in 2003–04 it was 254 eggs / annum. Seen in terms of the weight of eggs, the productivity per bird per year was 4.57 kg in 1961 and had increased to 11.27 kg in 2001. Rapid increase in productivity has come about in the 1980s, as is clear from **Figure 4.8**.

Figure 4.8: Average Productivity per Bird per Year



Source: www.faostat.fao.org

Poultry population in the country has been increasing over the years and has therefore been a contributory factor to the increase in egg production. However, the rate of growth of increase in egg production has always been much higher than that of the poultry population, implying the importance of productivity increase.

Table 4.11: Poultry Population, India

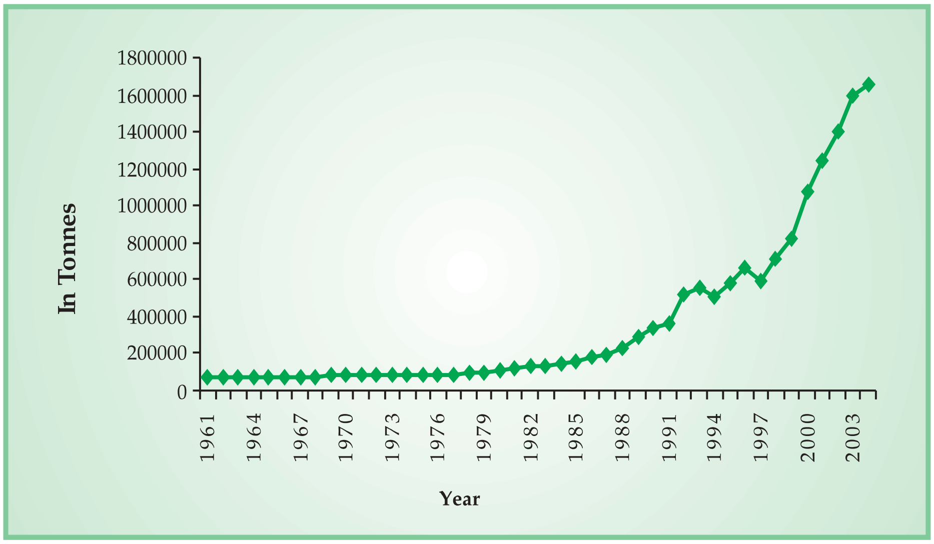
Year	Population in millions	Annual Compound Growth Rate
1951	73.50	
1961	114.20	4.51
1972	138.50	1.77
1982	207.74	4.14
1992	307.07	3.99
2003	489.01	4.32

Note: Growth rates correspond to 10 or 11 years (as the case may be) preceding the year of reference.
Source: Basic Animal Husbandry Statistics (2004)

4.3.2.2 Poultry Meat Production

India is among the top five chicken-meat producing countries in the world with the production of 1.65 million tonnes of chicken meat in the year 2004 (Government of India 2005–06). The concept of rearing poultry birds exclusively for meat purpose was not common until the 1980s in India. Since then, broiler production has gained momentum and hybrid broiler varieties such as Cobb, Ross, etc. have become popular. The broiler industry has been growing at phenomenal rates, with chicken meat production at 69 thousand tonnes in 1961 growing to 83 thousand tonnes in 1971 and 120 thousand tonnes in 1981. In the next 10 years it tripled to 360 thousand tonnes in 1991 and again tripled to 1250 thousand tonnes in 2001.

Figure 4.9: Poultry Meat Production in India



Source: www.faostat.fao.org

4.3.3 Technology Achievement Index — Poultry Sector

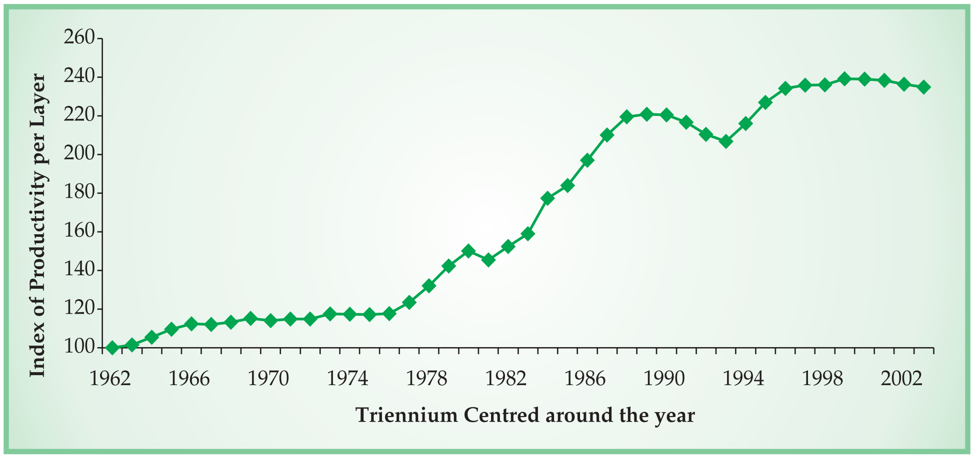
The Technology Achievement Index (TAI) for poultry is calculated using the productivity per layer as the indicator. Given that technological interventions in breeding, aided by improvements in feed and health, have contributed to the increase in productivity of layers, improvements in productivity of layers do reflect the achievement of technology. Data on yield of layers, in terms of weight of eggs, have been provided by FAO for the years 1961 to 2004. Average productivity of a layer was 4.9 kg per annum in triennium 1961 to 1963. This increased rapidly over the years and in triennium 2002 to 2004 it was 11.51 kg per annum. Equating the 1961–63 average productivity value to 100, TAI increased to 235 by 2002–04.

Table 4.12: Technology Achievement Index - Poultry Sector

Triennium average centred around the year	Average productivity per layer (in kg) per annum	Technology Achievement Index
1962	4.90	100
1972	5.63	115
1982	7.47	152
1992	10.31	210
2002	11.58	236

Source: www.faostat.fao.org

Figure 4.10: Technology Achievement Index - Poultry Sector



Source: Table 4.12

Box 4. 3 Small Ruminant Sector

India possesses 185.81 million small ruminants consisting of 61.46 million sheep and 124.35 million goats and by 2003, the country ranked second in world goat population and third in world sheep population (www.dahd.nic.in / relcensus.htm). Goat meat (chevon) and sheep meat (mutton) are important sources of meat production in the country. Small ruminants in India are raised essentially for meat and wool production. However, milk and manure are also important products.

Since Independence, various breeding strategies have been evolved for improving the body weight of the animals as well as the production and quality of wool. A number of sheep strains have been evolved in India through cross-breeding of indigenous sheep with superior temperate breeds such as Dorset, Suffolk, Rambouillet, and Merino. In addition, through selective breeding and intensive selection some of the important indigenous sheep breeds such as Malpura, Sonadi, Muzaffarnagari, Madras Red, Mandya, Nellore, and Deccani have been improved (ICAR 2002). For the improvement of local goats, some State governments have been distributing bucks of superior indigenous breeds, mostly Jamnapari, Barbari and Beetal, or stationing them in veterinary dispensaries for natural service.

The promising Indian sheep breeds that produce carpet wool are Chokla, Magra, Nali, Patanwadi, Maruari, Jaisalmeri, Pugal, Bhakarwal, Gurez, Gaddi, and Rampur Bushair. To improve the quality of wool from indigenous sheep, attention was given in the Fourth Plan to cross-breed native sheep with exotic fine wool breeds, and as a result, a few new fine wool sheep types such as Bharat Merino and Kashmir Merino were developed. A new superior carpet wool strain, Avikalin, was evolved at the Central Sheep and Wool Research Institute, Avikanagar, Rajasthan (ibid).

The importance of de-worming has been popularised by the Department of Animal Husbandry and Dairying, Government of India. Effective vaccines against diseases such as enterotoxaemia, haemorrhagic septicaemia, foot-and-mouth disease, sheep pox and peste de petite ruminants have been developed. Some of the important institutions involved in research on small ruminants are the Central Sheep and Wool Research Institute, Rajasthan; Central Institute for Research on Goats, Makhdoom; Indian Veterinary Research Institute; National Dairy Research Institute; and the various state agricultural / veterinary universities.

Mutton and chevon meat production in India nearly doubled from 3,57,400 tonnes in 1960–61 to 6,99,400 tonnes in 2000–01.

Box 4.4 Small Ruminant Development in Different Five Year Plan Periods

Second Five Year Plan (1956 –61)

- Evolvement of breeding policy for sheep
- Selective breeding of indigenous breeds in the plains and hills
- Upgradation of non-descript breeds with superior breeds
- Cross-breeding with foreign breeds in selected hilly areas

Third Five Year Plan (1961 – 66)

- Establishment of 15 sheep breeding farms and expansion of 17 farms with quality rams

Fourth Five Year Plan (1969 – 74)

- Establishment of 64 sheep and wool extension centres and wool grading-cum-marketing centres

Fifth Five Year Plan (1974 – 79)

- Encouragement of cross-breeding with woolly type sheep.

Note: No major development programme was initiated in subsequent plans.

4.4 Future Technologies

Future technologies in the livestock sector would be significantly bio-technologically oriented, contributing to developments such as diagnostic techniques for detecting genetic diseases like hereditary cancers and acquired diseases, therapies that use genes to cure diseases, and recombinant vaccines to prevent diseases. Advances will be in the line of *in vivo* and *in vitro* production of embryos, embryo transfer and production of clones and transgenic animals. Such transgenic animals, apart from being invaluable research tools for studying gene regulation, will also contribute to the production of pharmaceuticals, vaccines and rare chemicals. However, preservation of indigenous livestock biodiversity in genome banks is necessary. Stem cell-embryonic and adult research is gaining momentum among the scientific community, the results of which are expected to alleviate various ailments of animals and humans. Somatic cell cloning for biologically valuable protein production, organ transplantation and xeno transplantation, etc., will be among the future technologies in India (Birthal and Parthasarathy Rao 2002).

4.5 Conclusion

Various technological interventions in the post-Independence period in the livestock sector of the country have made significant improvements in the production, productivity and per capita availability of livestock products. Milk production in India was perceptibly low in 1960. To improve milk production in the country, multi-pronged approaches in breeding, health cover, feeding and marketing were initiated by the government through various development programmes. Cross-breeding and upgradation were done to improve the productivity of indigenous cows and local buffaloes, respectively. Vaccines against various diseases were developed and cattle in every part of the country were vaccinated by the government, which resulted in reduced animal losses as indicated by the disease incidence particulars.

Several feeding technologies were developed to exploit the full potential of cattle along with the creation of marketing facilities for rural milk. These combined measures resulted in improvement in milk production to 91 million tonnes in 2004, with India standing first in the world in milk production. The growth in the dairy sector was significant, as indicated by the two-fold increase in the value of output per milch animal.

In the poultry sector, along with the introduction of improved varieties of birds (both layers and broilers), development of newer vaccines and diagnostic kits, least cost formulation of feeds, and adoption of newer management techniques in rearing have contributed to improving productivity and production. The average productivity of birds in terms of weight of eggs increased more than twice between 1961 and 2001.

In small ruminants, de-worming and vaccination against various diseases resulted in increase in the production of mutton and goat meat.

REFERENCES

Balaraman, N. 2005. "Need for Organised Production". *The Hindu Survey of Indian Agriculture, 2005.* Pune: Kisan Forum Pvt. Ltd.

Basic Animal Husbandry Statistics. Various years. New Delhi: Ministry of Agriculture, Department of Animal Husbandry and Dairying, Government of India.

Birthal, Pratap S. and P. Parthasarathy Rao. 2002. "Technology Options for Sustainable Livestock Production in India". In *Proceedings of the Workshop on Documentation, Adoption and Impact of Livestock Technologies in India held at ICRISAT, Patancheru, India on 18-19 January 2001.* Addis Ababa: Systemwide Livestock Program, International Livestock Research Institute (ILRI).

Dantwala, M.L. (ed). 1986. *Indian Agricultural Development since Independence*. First edition. New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.

Dantwala, M.L. (ed). 1991. *Indian Agricultural Development since Independence.* Second edition. New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.

Desai, Anuradha. 2003. "An Overview of the Indian Poultry and Future Scenario". *Poultry Year Book, 2003 – 04.* Delhi: P. R. Gupta.

Economic and Political Weekly Research Foundation. 2004. *National Account Statistics of India 1950-51 to 2002-03*. Fifth edition. Mumbai.

Gaddi, G.M. and L.B. Kunnal. 1996. "Sources of Output Growth in New Milk Production Technology and Some Implications to Returns on Research Investment". *Indian Journal of Agricultural Economics.* 51 (3): 389-95.

Government of India. 1976. *Report of the National Commission on Agriculture 1976, Part VII: Animal Husbandry*. New Delhi: Ministry of Agriculture and Irrigation,

———. 2003. *Report of the Working Group on Animal Husbandry and Dairying for Tenth Five Year Plan*. New Delhi: Department of Animal Husbandry and Dairying, Ministry of Agriculture.

———. 2005–06. *Economic Survey*. New Delhi: Economic Division, Ministry of Finance and Company Affairs.

Gupta, P.R. (ed). 1997. *Dairy India*. Fifth edition. Delhi: P.R. Gupta.

Indian Council of Agricultural Research (ICAR). 2002. *Handbook of Animal Husbandry*. New Delhi.

Jain, T.B. 1986. "Poultry". In Dantwala et al (eds) *Indian Agricultural Development since Independence.* First edition. New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.

———. 1991. "Poultry". In Dantwala. Second edition.

Kumar, Anjani and U.K. Pandey. 1999. *Sources of Growth in the Livestock Sector.* Policy Paper 9. New Delhi: National Centre for Agricultural Economics and Policy Research.

Lalwani, Mahesh. 1989. "Technological Change in India's Dairy Farming Sector: Distribution and Decomposition of Output Gains". *Indian Journal of Agricultural Economics.* 44 (1): 55-86.

Narayankhedkar, S.G. 2003. "Current Status and Modern Trends in Commercial Poultry Breeding". *Poultry Year Book, 2003–04.* Delhi: P.R. Gupta.

National Dairy Development Board (NDDB). 1996. *Quarterly and Monthly Progress Reports on Operation Flood*. Anand.

Parthasarathy, S. 2001. *National Policies Supporting Small-holder Dairy Production and Marketing – India.* Paper presented at the NDDB-ILRI South-South Workshop on Small- holder Dairy Production and Marketing: Constraints and Opportunities.

Randhawa, M.S. 1986. *A History of Agriculture in India, Vol. IV*. New Delhi: ICAR.

Sadana, Vijay. 2004. "Compounded Poultry Feed Formulation". *All India Poultry Business Directory 2004.* Ghaziabad: Sadana Publishers and Distributors.

Shah, C.S. 1986. "Animal Husbandry". In Dantwala et al. First edition.

———. 1991. "Animal Husbandry". In Dantwala. Second edition

Singh, S.P. 2001. "Scientific Feeding of Dairy Cattle and Buffaloes". *Dairy India Year Book, 2000–01.* Delhi: P. R. Gupta.

Singh, Raj Vir, V.K. Saxena and D. Sharma. 2002. "Technological Developments in the Poultry Subsector". In *Proceedings of the Workshop on Documentation, Adoption and Impact of Livestock Technologies in India held at ICRISAT, Patancheru, India on 18-19 January 2001.* Addis Ababa: Systemwide Livestock Program, ILRI.

www.beef.org.nz/research/newsletters/feedconveff.asp/2005

www.dahd.nic.in

www.dahd.nic.in/relcensus.htm

www.e2necc.com/necc-beginning.html

www.faostat.fao.org

www.ivri.nic.in

www.karnal.nic.in/res_ndri.asp

www.nddb.org

www.nddb.org/institutions/ind-immu-ltd.html

www.oie.int/hs2/zi_pays.asp?c_pays=88&annee=2004 and 1996 www.pdonpoultry.org/history.html

www.planningcommission.nic.in/plans/planrel/fiveyr/10th/default.htm

www.thefreedictionary.com/Oocytes

5

FISHERIES*

5.1 Introduction

Fisheries deal with farming of aquatic organisms as well as their collection from open water. Farming of aquatic organisms is known as aquaculture and it is similar to agriculture, while open water fisheries or capture fisheries is akin to hunting. Aquaculture as well as capture fisheries can be undertaken in freshwater as well as marine environments. Over the years, the fish production system has been subjected to several technological interventions pertaining to production, processing, product formulation, packaging and storage. Intensification of fish culture with biotechnological tools, diagnosis and control of diseases that affect fish, improvement in fish nutrition from feed formulation to encapsulation, and assessment of water quality are some of the technological interventions pertaining to aquaculture that have been developed over the years in India. As far as capture fisheries are concerned, major technological intervention has been with regard to development of different kinds of fishing craft and gear.

This chapter discusses the technological interventions with regard to fisheries and the impact of these interventions on fish production and productivity in the country as a whole.

5.2 Fish Production in India

Fish production in India in the early 1950s was less than one million tonnes. Over the last five decades, fish production has increased significantly, and by triennium 2000–01 to 2002–03 it had reached 5.95 million tonnes (**Table 5.1**).[1] That is, over the last 50 years, fish production has increased at an annual compound growth rate of more than 4 % (**Table 5.2**). The structure of fish production has undergone remarkable changes over time. The contribution of inland fisheries to total fish production has increased significantly, from less than one-third of total production in 1951–52, to more than half in 2001–02. While the importance of marine fish production in the overall fish production scenario has been declining, it still accounted for a substantial proportion of fish production by 2001–02. However, in the 1990s, there appeared to have been a plateauing, but this was a global phenomenon and not unique to India. Overexploitation of the coastal stocks and variations in the physical, chemical and biological oceanographic parameters are some of the reasons attributed to the present scenario in the marine sector. As regards inland fisheries, the initial spurt came about in the 1960s and from then on production has been increasing steadily.

---

* Contributed by Mr. V. Senthilkumar, Project Associate, M.S. Swaminathan Research Foundation, Chennai

[1] In 2003–04 production further increased to 6.39 million tonnes, of which marine fisheries contributed 46 % and inland fisheries contributed 54 %.

Table 5.1: Fish Production in India, 1950-51 to 2000-01

(in million tonnes)

Triennium average centered around the year	Fish Production		
	Marine Fisheries	Inland Fisheries	Total Production
1951-52	0.48(65.75)	0.25(34.25)	0.73 (100.00)
1961-62	0.75(71.43)	0.30(28.57)	1.05 (100.00)
1971-72	1.07(61.49)	0.67(38.51)	1.74 (100.00)
1981-82	1.35(58.18)	0.97(41.81)	2.32 (100.00)
1991-92	2.44(59.36)	1.67(40.64)	4.11 (100.00)
2001-02	2.88(48.40)	3.07(51.60)	5.95 (100.00)

Note: Figures in parentheses indicate percentage to total fish production.

Source: Ministry of Agriculture (2004); Jhingran (1991)

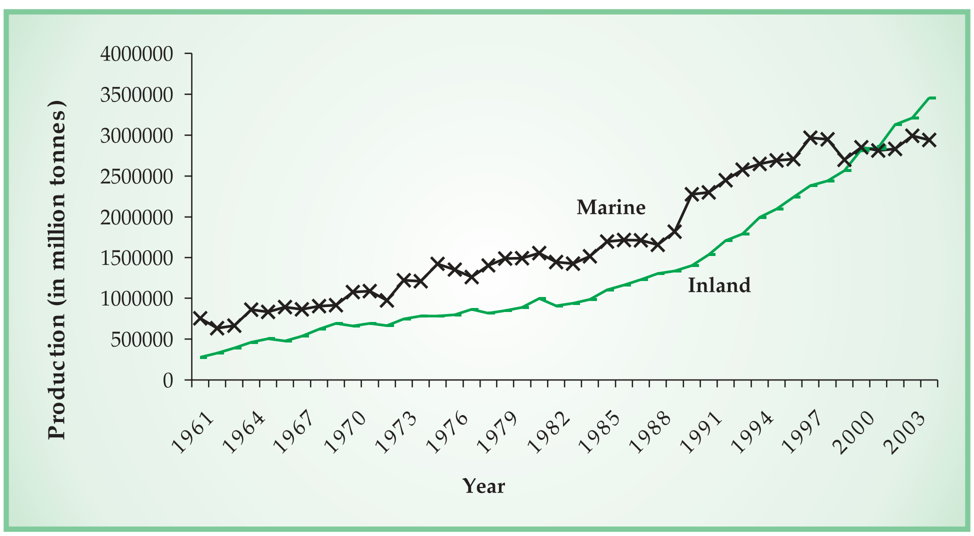
Table 5.2: Growth Rate of Fish Production

(in percentage)

Period	Annual Compound Growth Rate of Fish Production		
	Marine	Inland	Total
1951-52 to 1961-62	4.56	1.84	3.70
1961-62 to 1971-72	3.62	8.37	5.18
1971-72 to 1981-82	2.35	3.77	2.92
1981-82 to 1991-92	6.10	5.58	5.89
1991-92 to 2001-02	1.67	6.28	3.77
1951-52 to 2001-02	3.65	5.14	4.29

Source: Table 5.1

Figure 5.1: Fish Production in India



Source: Ministry of Agriculture (various years)

During the 1960s, inland fish production rose by 0.30 million tonnes and the contribution of inland fish production to total fish production rose from 28.57 % in 1961–62 to 38.51 % in 1971–72. The construction of new reservoirs in that decade contributed to the rapid increase in inland fish production. Since the 1980s, the growth in inland fish production has been related to growth in inland aquaculture. The rapid increase in fish production in freshwater aquaculture is due to significant technological interventions in the field.

The contribution of the fisheries sector to the gross domestic product (GDP) of the country has also been increasing. The share of fisheries in overall GDP went up from 0.44 per cent in 1950–51 to 1.18 % in 1999–2000 (at current prices) and the share of fisheries in agricultural GDP (Ag. GDP) increased more impressively during this period from a mere 0.77 per cent to 4.81 per cent.

Table 5.3: Contribution of the Fisheries Sector to GDP, India

Period	Percent Contribution of Fisheries to	
	GDP	Ag. GDP
1950-51	0.44	0.77
1960-61	0.53	1.13
1970-71	0.61	1.33
1980-81	0.74	1.91
1990-91	0.97	3.11
2000-01	1.18	4.81

Note: GDP - Gross Domestic Product; Ag. GDP - Agricultural Gross Domestic Product.

Source: Ministry of Agriculture (1991, 1996, 2000, 2004)

The steady increase in fish production over the five decades is largely related to several interventions made in the sphere of freshwater aquaculture as well as marine fisheries. The following sections discuss these interventions with specific reference to technology and institutions.

5.3 Interventions in Freshwater Aquaculture in India

Aquaculture is an age-old practice in India.[2] Aquaculture perhaps started when human settlements moved away from riverbanks to the hinterland. Paddy fields and low-lying areas in plains and those connected to estuaries and estuarine creeks became the cradle of aquaculture where inundation, caused either by monsoon rain or by tidal water, brought in the natural seeds of finfish and shellfish which were automatically trapped after the water receded. This eventually gave rise to the operation of ‘trapping and holding’ of fish seeds and raising them to table-size fish, and marked the beginning of aquaculture in India. In colonial India, freshwater fish culture was mainly confined to Bengal, Bihar and Orissa until about the end of the 19th century after which it gradually spread to the other States. At the beginning of the 20th century, freshwater fish culture gained prominence in Tamil Nadu when the first big fish farm with facilities for breeding, rearing and stocking of carp came into existence. (Jhingran 1991). In the post-Independence period, the R&D efforts of the Indian Council of Agriculture Research (ICAR) have played an important role in development and dissemination of technology related to aquaculture.

[2] Kautilya’s *Arthasastra*, written between 321 and 300 B.C., indicates that fish culture activity in India dates back 2000 years. Another document that describes methods of fattening of fish in ponds is the encyclopedia of King Someswara, *Manasoltara,* compiled in 1127 A.D. (Jhingran 1991).

5.3.1 Institutional Interventions

Freshwater aquaculture research was initiated in the pond culture division of the Central Inland Fisheries Research Institute[3] (CIFRI) established in 1947 in Barrackpore, Calcutta, West Bengal. In 1949, a pond culture sub-station of the Institute was established in Cuttack, Orissa, with a view to finding solutions to problems of fish culture in ponds and village tanks. The primary focus of research in this sub-station was freshwater aquaculture while the parent Institute focused on inland capture fisheries. The technology of scientific carp culture was developed in Orissa. Since 1967 CIFRI has become part of ICAR. In 1971, ICAR initiated an All India Coordinated Research Project on composite fish culture and fish seed production for demonstrating composite carp culture technology in different agro-climatic zones. In 1977, to give emphasis to freshwater aquaculture research, CIFRI established the Freshwater Aquaculture Research and Training Centre (FARTC) in Bhubaneswar, Orissa. The Centre became an independent Institute in 1987 and was called the Central Institute of Freshwater Aquaculture (CIFA). CIFA has virtually revolutionised freshwater aquaculture in the country by standardising three technologies: (i) induced breeding of carp through administration of pituitary gland extract; (ii) carp nursery rearing and pond management practices; and (iii) composite carp culture. It is also the lead centre on carp farming in India under the Network of Aquaculture Centres in the Asia-Pacific region.

In addition, the Central and State governments have also taken efforts to promote inland fisheries production. One of the most important and effective national programmes[4] for the promotion of rural aquaculture development has been the Fish Farmers Development Agencies (FFDAs), started in 1973–74. FFDAs provided a package of technical, financial and extension support services to fish farmers. They arranged suitable water areas on long-term lease, identified beneficiaries, and provided incentives in the form of subsidies/grants for the construction/rehabilitation of ponds and for input supplies. FFDA's primary objective was to lease out water areas to individuals, groups or cooperatives (Srivastava et al. 1993). Krishi Vigyan Kendras (KVKs) were also established in different parts of the country in 1974 to disseminate modern technology related to aquaculture practices to fish farmers.

Table 5.4: Overall Performance of FFDAs, India

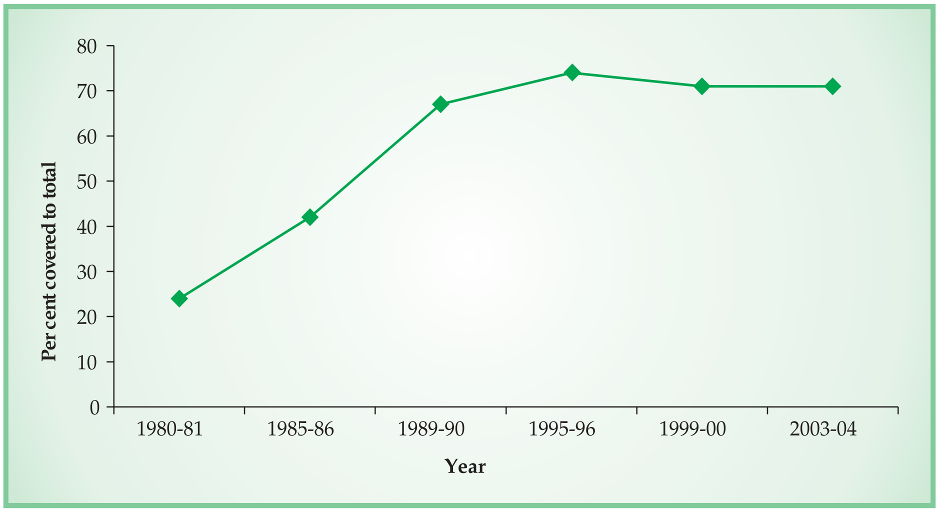
Year	Total number of districts in India	Number of districts where FFDA have been in operation	Water area covered by FFDA (ha)
1980-81	412	98	NA
1985-86	439	184	1,20,462
1989-90	466	313	2,46,031
1995-96	558	414	3,87,498
1999-00	593	422	5,31,229
2003-04	604	429	6,49,458

Source: Ministry of Agriculture (1991, 1996, 2000 and 2004)

[3] In the period 1986-2003, CIFRI was named as Central Inland Capture Fisheries Research Institute.

[4] FFDA is a centrally-sponsored scheme where the expenditure is shared on a 75:25 basis between the Government of India and the respective State government.

Figure 5.2: Percentage of Districts Covered by FFDAs



Source: Table 5.4

From **Table 5.4** and **Figure 5.2**, it is clear that over the years the presence of FFDA across districts has improved. During the 1990s, more than 70 % of districts were covered by the FFDA programme.

5.3.2 Technological Interventions[5]

While aquaculture has always been practised in India, a significant upward shift occurred as a result of major technological interventions. During the post-Independence period the country has made tremendous strides in inland fishery resources. In this study, carp culture is considered the most significant and catalytic technological intervention that has formed the basis for the rapid growth of freshwater aquaculture in rural India. Induced breeding and development of hatcheries for carp is undoubtedly a significant development that has promoted the practice of carp culture in India.

5.3.2.1 Carp culture

Carp culture in India originated traditionally as the polyculture of Indian major carp catla *(Catla catla)*, rohu *(Labeo rohita)*, and mrigal *(Cirrhinus mrigala)*. Polyculture implies incorporation of more than one species with different feeding habits and different habitat preferences. The technique of composite fish culture involves the introduction of Indian and exotic high yielding carp in a confined water body. In the late 1950s, composite fish culture was adopted in India using the Bangkok strain of common carp (*Cyprinus carpio*) and Chinese carp like silver carp (*Hypopthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*) with the three Indian major carp. In composite fish culture, different niches of a pond are effectively utilised and the productivity of per unit water spread area also gets multiplied as the fishes have different feeding habits. For instance, catla and silver carp are surface feeders, rohu is a column feeder, mrigal and common carp are bottom feeders and grass carp is an herbivore (**Table 5.5**). Thus when more fingerlings of different species are cultivated per unit of water body, efficient utilisation of the water body takes place.

[5] This section is based on discussions with experts in this field as well as on a survey of literature. We are grateful to several eminent scientists who have been kind enough to give us their valuable time for discussion. We would particularly like to thank Dr. S. Ayyappan, DDG (Fisheries), ICAR, Professor P. Selvaraj, retired professor, FCRI, Thoothukkudi, and scientists of CIFA. We have drawn heavily from the following sources: Jhingran (1991) and Pillai and Katiha (2003).

Table 5.5: Feeding Behaviour of Different Species of Carp

Species	Feeding habit	Feed	Habitat
Catla catla (catla)	Surface feeder	Plankton	Surface
Labeo rohita (rohu)	Predominantly column feeder	Planktophage	Column
Cirrhinus mrigala (mrigal)	Bottom feeder	Omnivore	Bottom
Hypopthalmichthys molitrix (silver carp)	Surface feeder	Phytoplanktophage	Surface
Cyprinus carpio (common carp)	Bottom feeder	Omnivore	Bottom
Ctenopharyngodon idella (grass carp)	Herbivore	Mainly aquatic plants	Column

Source: Handbook of Fisheries and Aquaculture (2006)

In composite fish culture, pond water is fertilised with organic and inorganic fertiliser or wastewater to enhance the live feed production for the fingerlings. Sometimes biogas slurry is also used. Fish is normally fed with rice bran and oil cake. In higher stocking densities, formulated feed is given and pond water is also aerated or changed to support a very high biomass. But using formulated feed or aerating the water is beyond the means of common farmers. Freshwater pond aquaculture production system, which is photosynthesis dependent, is therefore most suited to poor resource farmers. Polyculture of Indian major carp or composite fish culture with exotic carp are also undertaken with or without fertilisation and feed-based systems when practised in community tanks and integrated systems.

Adoption of techniques in polyculture of carp and composite fish culture has been with several modifications depending on the market demand and resource availability.

5.3.2.2 Induced Breeding of Carp

A major constraint to the speed and extent of development of carp culture is the availability of carp seed, i.e., fry and fingerlings. A common practice in the past has been to collect carp seed from natural sources. Their occurrence has been limited by the spawning period of the fish (usually short), meteorological and water conditions, and their vulnerability to predation. Natural fry grounds were often distant from fish farming localities, and apart from high expenses involved in transportation, there was often heavy mortality of larvae and fry. Moreover, fish seed collected from natural habitats were usually composed of several species, some of which were unsuitable for culture, and as yet there is no practical method for separating the desirable species from the others.

To ensure a reliable supply of quality fish seed, various techniques have been developed for breeding pond fish under controlled conditions. Some are simple ones requiring only elementary changes in environmental conditions, while others require sexual segregation of mature specimens or substrates for attachment of eggs. The most sophisticated technique has been the use of hormones (hypophysation) to induce breeding. This was the crucial step in the evolution of freshwater fish culture in India, and it paved the way for production of true-to-species seed fish, which had not been possible earlier. The credit for induced breeding of Indian major carp goes to CIFRI scientists.[6]

Induced breeding of carp is the application of pituitary gland extract injections[7] (hypophysation) for successful spawning. Brazil was the first country to develop a technique for hypophysation. This

[6] Credit for this technology is attributed to Chaudhuri and Alikunhi (*Current Science,* 1957, No.12).

[7] Two methods of injection are widely practised: intramuscular, in the flank just below the dorsal fin and behind the gill cover, which is safer but works slowly; and interperitoneal, into the body cavity, which is faster acting but involves a greater chance of injury or death (www.wikipedia.org)

technique has evolved over many years of research. Khan made the first attempt[8] in 1937, in which he employed mammalian pituitary hormones and succeeded in inducing ovulation in *Cirrhinus mrigala* (mrigal). Chaudhuri in 1955 was the first to successfully induce *Esomus danricus* to breed by intraperitoneal injection of catla pituitary gland extract. He also bred *Pseudeotrophus atherionoides* by administering pituitary gland extract from *Cirrhinus reba*. Ramasamy and Sundararaj reported successful breeding of catfishes, *Heteropneustes fossilis* and *Clarius batrachus*, during 1955 and 1956, respectively, by hormone injection (Jhingran 1991). Chaudhuri and Alikunhi in 1957 succeeded in inducing *Labeo rohita*, *Cirrhinus mrigala*, *C.reba*, *Labeo bata* and *Puntius sarana* to breed by injecting them with carp pituitary extracts. Chinese carp have also been bred successfully in 1962 by employing similar techniques(ibid). In India, procurement of pure seed of cultivable fishes from a dependable source posed a problem until the technique of hypophysation was successfully applied to Indian major carp during the period 1957–59.

Commercial carp hatcheries mainly used carp pituitary gland extract for breeding purposes. The breakthrough achieved in isolation and characterisation of gonadotropin releasing hormone (GnRH) from salmon led to the development of a commercial product known as Ovaprim by Syndel Laboratory, Canada, and marketed by Glaxo India Ltd. in the 1990s. By the late 1990s two more products were in the market in India: Ovatide, reported to give a similar result at almost half the price, manufactured by Hemmo Pharma, Mumbai and Wova-FH, released by Wockhardt (Ayyappan and Jena 2001).

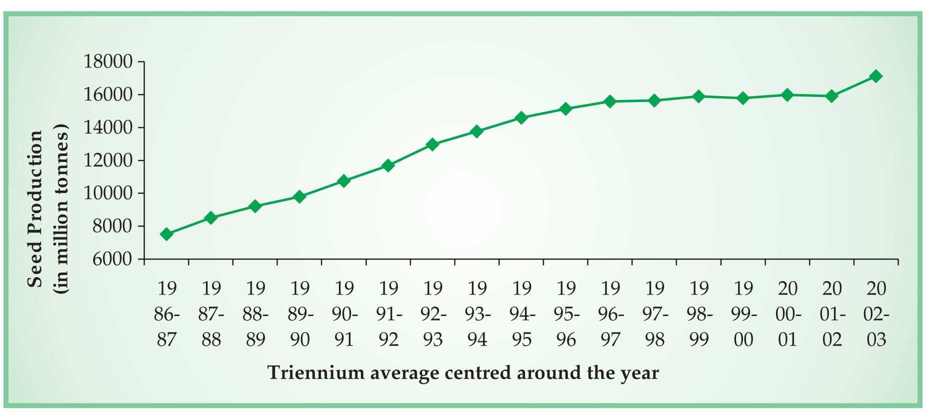
5.3.3 Measures of Impact of Technological Interventions in Aquaculture

It is a well recognised fact that since the 1980s the spread of technologies related to carp culture has led to an increase in fish production in inland fisheries and therefore in the contribution of inland fisheries to the total fish production of the country. Within the inland fisheries sector the importance of aquaculture over capture fisheries has increased. The direct impact of the carp culture technologies can ideally be measured with the changes in aquaculture production as well as productivity over a period of time. Unfortunately, the database for inland fisheries, and aquaculture in particular, is very poor in our country.

5.3.3.1 Seed

Supply of seed is an important requisite for the spread of composite fish culture. Fish seed production with the development of hatcheries has played a significant role in the development of freshwater aquaculture. **Figure 5.3** indicates the growth in fish seed production.

Figure 5.3: Fish Seed Production, All India



Source: Ministry of Agriculture (various years)

[8] Khan (1938) as cited in Jhingran (1991)

In the mid-1980s, production of fish seed was lower than 8000 million fry and over a decade it had nearly doubled. By 2002–03 fish seed production accounted to 17,000 million fry. The direct impact of the technology of induced carp breeding has resulted in a major shift from riverine seed collection to hatchery seed production (Sinha 1999). Undoubtedly, induced carp breeding has made the development of carp hatcheries in the country possible.

5.3.3.2 Adoption of Freshwater Aquaculture Technologies

As there is no secondary data on the extent of adoption of different carp culture technologies, it is necessary to rely on field studies conducted across different parts of India to gather this information. Pillai and Katiha conducted a field level study in a few major aquaculture States such as West Bengal, Orissa, Andhra Pradesh, Uttar Pradesh and Karnataka during the year 2000. Their findings clearly show the significance of carp culture technology in freshwater aquaculture. Forty percent of farmers had adopted polyculture of carp, while another 35 % had gone in for composite fish culture and 15 % for integrated fish farming.

Table 5.6: Adoption of Freshwater Aquaculture Technologies by Farmers

Technology	All India Average (in per cent)
Polyculture of carp	39.82
Composite fish culture	34.53
Integrated fish farming	15.04
Sewage-fed fish culture	6.58
Husbandry of carp fingerling	3.29
Monoculture carp	0.75
Total	**100.00**

Source: Pillai and Katiha (2003)

The level of diffusion of carp culture technology is measured not only by the number of farmers adopting this technology, but also by the extent of water spread area where this technology is practised. The area covered by carp culture technology as a percent of total available potential water area is used as an indicator of technology diffusion. Using this indicator for the period 1980 to 2003, a technology diffusion index has been computed.

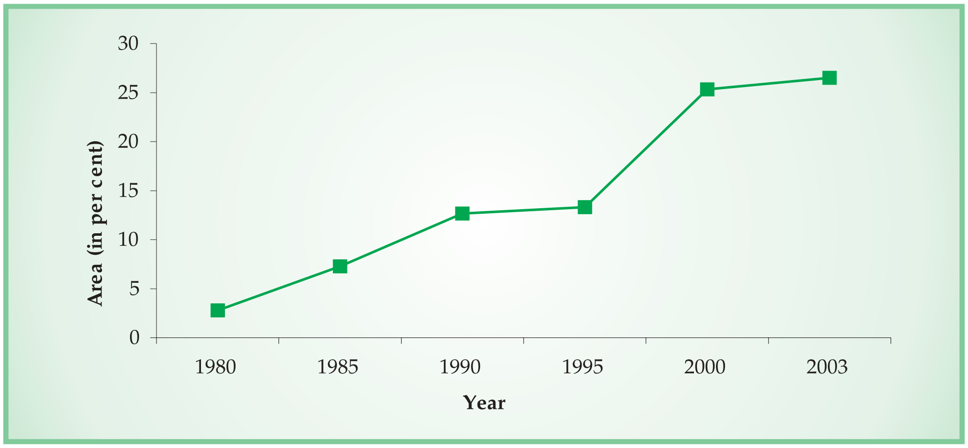
Table 5.7: Index of Technology Diffusion - Carp Culture

Year	Potential area available as tanks and ponds (lakh ha.)	Water spread area covered by carp culture (lakh ha.)	Per cent of area covered by carp culture	Index of Technology Diffusion
1980	10.80	0.3	2.78	100
1985	16.50	1.2	7.27	262
1990	22.12	2.8	12.65	455
1995	28.55	3.8	13.30	478
2000	22.50	5.7	25.33	911
2003	24.14	6.4	26.51	954

Note: The index is calculated by using the formula $I = (A_t / A_o)*100$. where A_t is the percent area covered by carp culture in year t ; Ao is the percent area covered in the base year, 1980.
Source: Ministry of Agriculture (1991, 1996, 2000, 2004); Jhingran (1991)

From **Table 5.7** it is clear that a rapid spurt in carp culture technology has occurred in the late 1990s. But even by 2000, only 25 % of potential water spread area had been covered, indicating great scope for diffusion of this technology in the future. **Figure 5.4** shows the trend in adoption of carp culture technology.

Figure 5.4: Trend in Percent Area Covered by Carp Culture

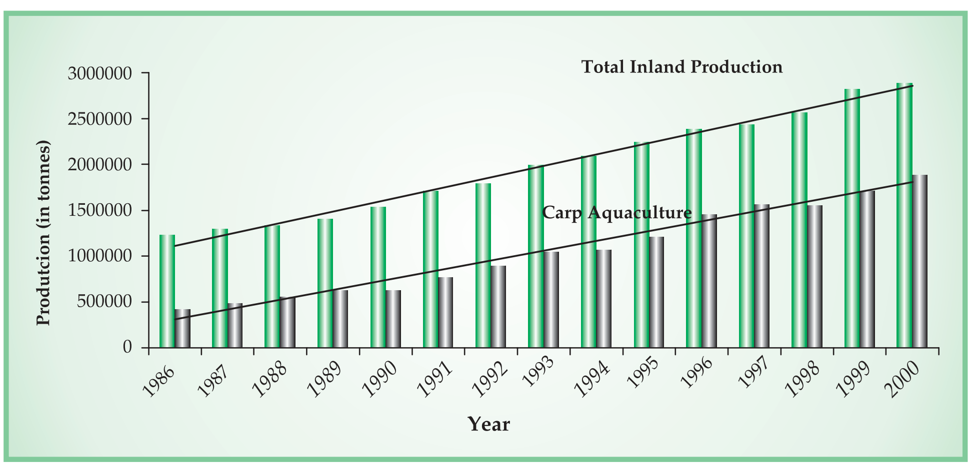


Source: Table 5.7

5.3.3.3 Carp Production, Productivity and Profitability

Carp culture technology has resulted in significant increase in freshwater aquaculture production since the 1980s. To understand the pattern of development in carp production and productivity we draw upon two sets of data sources: statistics provided by FAO on world aquaculture production and statistics collected from farmers associated with FFDA. The trend in carp aquaculture production is depicted in **Figure 5.5**. Here the aquaculture production statistics of catla, rohu, mrigal, grass carp, silver carp and common carp have been considered. It can be seen that the production has increased significantly over the fifteen-year period from 1986 to 2000. From a production level of over 4 lakh tonnes in 1986, it increased to nearly 19 lakh tonnes by 2000.[9] The percentage contribution of carp aquaculture production to total inland fish production has increased from 34 % in 1986 to 65 % in 2000 **(Table 5.8)**.

Figure 5.5: Carp Aquaculture Production and Total Inland Fish Production



Source: Table 5.8

[9] This data is available only from 1986 onwards.

Table 5.8: Index of Carp Aquaculture Production, India

Year	Aquaculture Carp Production (tonnes)	Inland Fish Production(tonnes)	Percent of carp production to total inland production
1986	418,000 (100)	12,28,880	34.01
1987	487,000 (117)	13,00,920	37.44
1988	557,000 (133)	13,34,600	41.74
1989	626,000 (150)	14,02,000	44.65
1990	628,157 (150)	15,36,250	40.89
1991	765,581 (183)	17,09,330	44.79
1992	894,801 (214)	17,89,050	50.02
1993	10,43,954 (250)	19,95,500	52.32
1994	10,67,280 (255)	20,96,730	50.90
1995	12,11,033 (290)	22,42,320	54.01
1996	14,59,506 (349)	23,81,430	61.29
1997	15,60,020 (373)	24,38,040	63.99
1998	15,51,437 (371)	25,65,810	60.47
1999	17,12,193 (410)	28,22,700	60.66
2000	18,84,522 (451)	28,84,483	65.33

Note: Figures in parentheses provide the index w.r. to year 1986.

Source: FAO (1990, 1995, 2000); Ministry of Agriculture (1990, 1996, 2000)

It is estimated that by 2000, both Chinese and indigenous carp have accounted for nearly 80 % of the freshwater aquaculture production in India (Planning Commission 2001). As shown in **Table 5.7,** the increment in production is also due to proportionate expansion in water area covered for aquaculture purpose. The rapid increase in carp production has resulted in the growth of per capita availability from 0.54 kg / annum in 1986 to 1.84 kg / annum in 2000.

A large number of fish ponds in India are rainfed and therefore aquaculture practices cannot be carried out all around the year in these ponds. Village ponds and tanks have multiple uses and therefore management and maintenance of ponds, particularly input use, becomes difficult. The only record available for carp culture productivity is FFDA statistics and the individual studies conducted by research institutions. The FFDA programme has a major share in the success of the composite fish culture technology. The different time period performance of the FFDA programme is presented in **Table 5.9**, which clearly shows the growth and success of composite fish culture technology.

Table 5.9: Average Productivity over Time in FFDA Ponds, India

Year	Average Productivity (Kg/ha)	Annual Compound Growth Rate (per cent)
1970-71	600	------
1980-81	700	1.55
1985-86	1,500	16.47
1989-90	1,865	5.60
1995-96	2,180	2.64
1999-00	2,226	0.52

Source: Ministry of Agriculture (1991, 1996, 2000); Jhingran (1991)

In the earlier years while wild seed and naturally available feeds were used, production was in the range of 50 to 400 kg / ha / yr. After the implementation of the All India Coordinated Research Project in 1971, the initiation of FFDA in 1973–74, and the spread of induced breeding technology, the average productivity has increased nearly four times. The rapid spurt in productivity has come about in the first half of the 1980s with an annual compound growth rate of nearly 16.5 %. After the initial spurt, productivity has slowed down, and while it still remains positive, it has been more or less stagnant in the late 1990s.

Pillai and Katiha (2003) noted that while the average national productivity from still- water ponds has gone up over the last two decades, the range of increase varies widely across farmers. By 2000, while the average productivity was about 2 t / ha / yr, some farmers even had productivity levels of 8 to 12 t / ha / yr through intensive carp culture. The average productivity figures hide the wide variation in productivity levels related to differences in ownership of ponds / farms, in farm sizes and across space. A study conducted in the Kolleru lake region from 1998 to 2002 noted that the average productivity in tanks belonging to fishermen co-operative societies was of the order of 2t / ha with a maximum of 3t / ha in 1980; while the productivity in private fish pond ranges for the year 1980 was a minimum of 2.5t / ha to a maximum of 7.5 t / ha. The study noted that during the project period, productivity levels of private farms improved rapidly, varying from 10.02 t / ha / yr to 13.87 t / ha / yr. Productivity is also related to the size of pond — the larger the size, the greater is the productivity (Saha 2002).

We have to rely on micro-level field-based studies for an understanding of aspects related to the costs and benefits of fish production. Pillai and Katiha (2004) have published costs and returns of freshwater aquaculture technologies on the basis of their study.

Table 5.10: Costs and Returns (Rs/ha/year) in Freshwater Aquaculture

Particulars	Carp polyculture		
	Low input	Medium input	High input
Lease value	10,000	10,000	10,000
Pond preparation	7,500	7,500	7,500
Fertilisers and lime	10,000	7,500	7,500
Fingerlings (seed)	3,500	7,000	20,000
Fish feed	-------	60,000	2,00,000
Labour	5,000	15,000	30,000
Miscellaneous	3,000	5,000	10,000
Interest	2,925	8,400	21,375
Total cost	**41,925**	**1,20,400**	**3,06,375**
Fish yield (t / ha)	2.5	6.0	12.5
Gross returns	75,000	1,80,000	3,75,000
Profits	33,075	59,600	68,625

Source: Pillai and Katiha (2004)

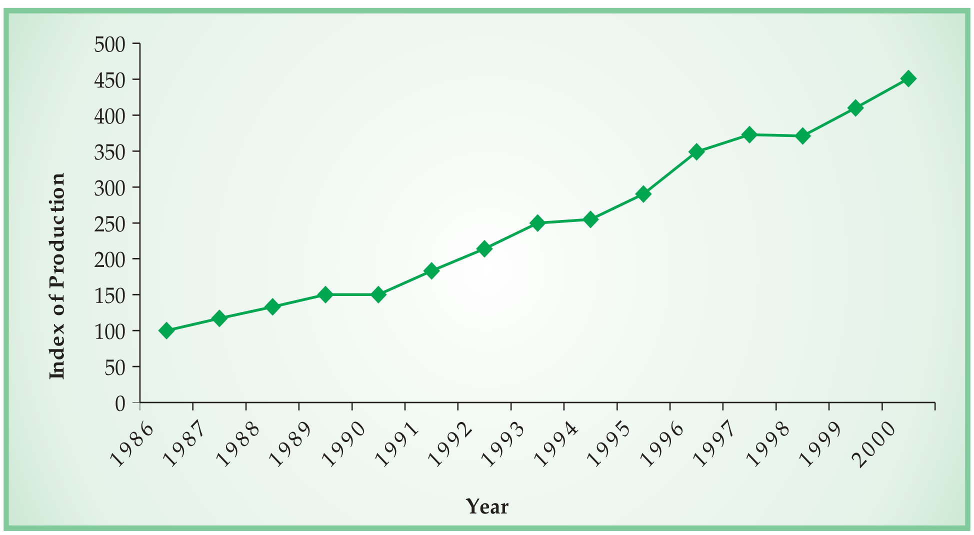
From **Table 5.10** it is clear that fish yield is directly related to expenditure on seed, feed and overall management. Fish yield in high input production systems is twice that in medium input systems and five times as high as that in low input production regimes. Profit earned per hectare is also much higher in high input production regimes compared to medium and low input ones.

An analysis of total factor productivity (TFP) with regard to aquaculture for the period 1992–98 covering 27 States of India, attempted by Praduman Kumar (Kumar 2004), shows that TFP has grown 4.01 % in the six years. According to this study, while the input index moved 20 points, the output index moved 45 points over 1992 to 1998, clearly indicating the positive impact of technology on the aquaculture sector in India. The study further points out that the most limiting factor in output growth is availability of pond area.

5.3.3.4 Technology Achievement Index — Freshwater Aquaculture

Given that the rapid increase in carp production is undoubtedly related to carp culture technology, carp production can be used as an indicator of technological achievement. Using the carp production data of 1986 as the base, an index of technology achievement has been worked out for the period 1986 to 2000. In 1986 the level of carp production was 4.18 lakh tonnes and this increased to 18.8 lakh tonnes in 2000. Equating the 1986 production level to 100, the technology achievement index has risen to 451 in the year 2000, a four-fold increase. However, it is important to note that the increment in production is also due to proportionate expansion in water area covered for aquaculture purposes and cannot be attributed only to technological changes.

Figure 5.6: Technology Achievement Index - Freshwater Aquaculture



Source: Table 5.8

5.4 Interventions in Marine Fisheries in India

The Indian marine capture fisheries sector has witnessed rapid growth in quantitative as well as qualitative dimensions in the last five decades. Even while the importance of marine fisheries in overall fish production has declined, production from marine fisheries increased more than five-fold over the period 1951–52 to 2001–02 (**Table 5.1**). This rapid increase is related to technological developments in harvesting methods, extension of fishing into relatively deeper regions, and overall increase in fishing effort. Fleet size and operations have undergone quantitative and qualitative changes over the years. Traditional boats are being increasingly motorised and the mechanised sector operating with trawlers and gill-netters are resorting to multi-day fishing. India has a long coastal length of 8129 km with a continental shelf[10] of over 0.5 million sq. km and an Exclusive Economic Zone[11] (EEZ) area of 2.02 million sq. km. There are 12 maritime States and Union Territories in India.

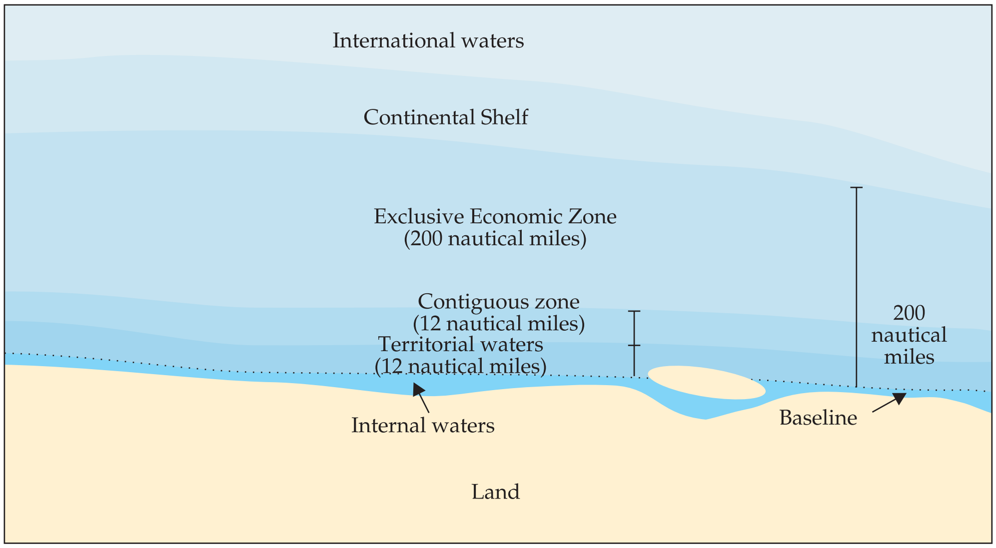
Box 5.1 **Shrimp Farming**

In India, shrimp farming has been traditionally practised in the coastal states of West Bengal and Kerala. The traditional *trap and culture* system was characterised by low production levels of mixed species of fin and shellfishes. The importance of introducing scientific farming techniques to increase production and productivity was felt and ICAR implemented an all India coordinated research project on brackishwater fish farming (1973- 1984) to develop and test various farming technologies under different agro-climatic conditions of the country. The main centre of the project was located in West Bengal and other centres were located in Orissa, Andhra Pradesh, Tamil Nadu, Kerala and Goa for demonstrating the technologies to small-scale farmers. Simultaneously, shrimp hatchery technology was also introduced into the country and two commercial hatcheries were established in the late 1980s with the initiative of the Marine Products Export Development Authority. With the establishment of hatcheries in the private sector, the country witnessed a faster development of shrimp farming from 1990–1994. In 2006, there are 300 shrimp hatcheries, 90 % of them in Tamil Nadu and Andhra Pradesh. The culture practice was also gradually intensified and varied levels of intensification were noticed depending on the investment capabilities of the farmer. Stocking densities of 2 to 30 nos/ sq.m were used under different systems by the farmers. Shrimp culture was affected by health and disease problems. Initially, in the early 1990s some bacterial diseases were noticed which were more or less localised and the mortality levels were not very high. Later in 1995, viral diseases such as monodon baculo virus and white spot syndrome virus affected the farmed shrimp and there was a slump in shrimp farming. Reasons such as heavy stocking densities and poor farm management practices were attributed to the outbreak of shrimp diseases in the country. In 1996, following court verdicts and the establishment of the Aquaculture Authority with powers to issue licenses and guidelines, the shrimp culture sector is gradually going through a regulated regime. The aquaculture shrimp production has registered a growth from 0.6 lakh tonnes in 1990–91 to 1.9 lakh tonnes in 2002–03.The shrimp farming areas are mainly located in the coastal states of Andhra Pradesh, West Bengal, Kerala, Orissa, Tamil Nadu, Karnataka, Maharashtra, Gujarat and Goa. The major importers of Indian shrimp are Japan, Western Europe and USA. There were 33 feed mills in the country in 2005 with a total installed capacity of 1,50,000 t/year to cater to the shrimp industry. In 1988, in the total shrimp exports from India, cultured shrimp contribution was 33 % in quantity and 49 % in value. This rose to 58 % and 86 %, respectively, in 2000.

[10] Continental shelf is the seabed and sub-soil of the sub-marine areas adjacent to the coast, extending to a depth of 200 metres.

[11] Under the international Law of the Sea, an Exclusive Economic Zone (EEZ) is a sea zone over which a country has special rights over the exploration and use of marine resources. Generally a country's EEZ extends to a distance of 200 nautical miles (370 km) out from its coast, except where resulting points would be closer to another country (www.wikipedia.org).

Figure 5.7: Sea Zones



Source: www.wikipedia.org

In analysing the development of marine fisheries over 1950 to 2000, three distinct phases can be identified: 1950 to mid 1960s; mid 1960s to mid '80s; mid 1980s to 2000. In the first phase, fishing was predominantly with indigenous craft and gear and the process of mechanisation was in its initial stages of development. The second phase was marked by substantial increase in the use of synthetic gear materials, use of mechanised craft, establishment of fishing harbours, initiation of purse seine[12] and initiation of motorisation of country craft. Export trade also improved during this period (Srinath 2003). During the third phase, there was substantial growth in the motorisation of the artisanal fleet, increase in the use of ring seine, extension of fishing grounds, and increase in fishing hours by resorting to voyage fishing and introduction of seasonal closure of fisheries.

5.4.1 Institutional Interventions

International as well as national institutions have been engaged in developing various measures to improve production in marine fisheries. At the national level, three different Central Ministries deal with marine fisheries: Ministry of Agriculture,[13] Ministry of Science and Technology[14] and Ministry of Commerce.[15]

[12] A seine is a large fishing net that hangs vertically in the water by attaching weights along the bottom edge and floats along the top. A common type of seine is a purse seine, named such because along the bottom are a number of rings. A rope passes through all the rings, and when pulled, draws the rings close to one another, preventing the fish from "sounding", or swimming down to escape the net. This operation is similar to a traditional style purse, which has a drawstring. Ring seine is a smaller modified one. (www.wikipedia.org)

[13] Integrated Fisheries Project (IFP), Central Institute of Fisheries Nautical Engineering and Training (CIFNET), Fishery Survey of India (FSI) and Central Institute of Coastal Engineering for Fishery (CICEF), and the ICAR institutes are under Ministry of Agriculture.

[14] Department of Science and Technology (DST), Department of Ocean Development (DOD), Department of Biotechnology (DBT) and the Council for Scientific and Industrial Research (CSIR) with National Institute of Oceanography (NIO) are under Ministry of Science and Technology.

[15] Marine Products Export Development Authority (MPEDA) is under Ministry of Commerce.

At the State level, fisheries colleges affiliated to State agriculture universities, and the fisheries departments are concerned with the development of the marine fisheries sector. The Central Marine Fisheries Research Institute (CMFRI), Cochin, is the nodal agency in India responsible for research support to the development of marine fisheries in the country. The Government of India under the Ministry of Agriculture established the Central Marine Fisheries Research Institute in 1947 in Mandapam, Tamil Nadu, and it became a member of the Indian Council of Agricultural Research (ICAR) in 1967. The headquarters was shifted from Mandapam Camp to Cochin in 1971. At CMFRI, research efforts were initially devoted to estimation of marine fish landing, taxonomy of marine organisms, and bio-economic characteristics of exploited finfish and shellfish stocks. In the early 1970s, recognising the need to supplement capture fisheries production with that from sea farming and coastal mariculture, the development of many viable mariculture technologies (shrimp, edible oyster, mussel, clam, pearl oyster and sea weed) was given priority. In the 1990s, research was concentrated in augmenting marine fisheries production through programmes like sea ranching (shrimps, clams, pearl oysters) and setting up of fish aggregating devices (FADs) as community programmes in fishing villages. The Agricultural Technology Information Centre (ATIC) at CMFRI was established in 2001 to provide a single window delivery system for the transfer of these technologies, apart from the existing facilities like Krishi Vigyan Kendras (KVKs) and Trainers Training Centres (TTCs) (www.cmfri.nic.in).

In 1953, an agreement was reached between the Government of India and FAO regarding technical assistance in small craft mechanisation and gear technology. Thus between 1954 and 1958, FAO experts in India tried to develop three prototypes of mechanised surf boats but partly succeeded only in 1963. In addition to higher initial costs, the surf boats could operate only gill nets while an open mechanised boat could operate gill nets and trawling / long lining. The Indo-Norwegian Project (INP) was set up in 1953 at Quilon in Kerala following a tripartite agreement signed by the Governments of Norway, India and the United Nations with the aim of mechanising the Indian fisheries sector (Pillai and Katiha 2004). Technological research in the fisheries sector did not receive much attention in India until the establishment of the Central Institute of Fisheries Technology (CIFT) in 1954, which supported research in the design of various fishing craft, gear, fishing techniques, methods of handling and post-harvest processing, and utilisation. Since 1963, INP's activities have been directed more towards exploratory and experimental fishing while CIFT took up R&D work in craft / gear technology, concentrating on the following aspects:

- New designs for mechanised craft
- Indigenous engines
- Alternative materials for boat building
- New materials and designs of nets
- New methods of fishing

A notable feature of the craft types developed by CIFT has been their ability to be used simultaneously for trawling as well as for other kinds of fishing, with suitable modifications in the deck layout. Twelve standard designs were developed, which were capable of trawling as well as hand lining, gill netting and purse seining. Also developed were cheaper and suitable boat-building materials as well as engine designs for better performance (Korakandy 1994).

The International Indian Ocean Expedition (1959–65) and the Pelagic Fisheries Project (1971–75) were also initiated with FAO / UNDP collaboration. The Bay of Bengal Programme (BOBP), financed by the Swedish International Development Agency from 1977 to 1989, also brought about significant changes in the life of the artisanal fishermen of India by popularising beach landing craft and craft motorisation. Introduction of new net designs, initiating post-harvest technologies like hygienic curing and smoking of fish, introduction of insulated fish boxes for transportation from landing centres to markets, and the enhanced role of fisherwomen in coastal fishery development were other interventions. Around the same time, the FAO / UNDP / CIFNET experiments on fuel-saving devices also came up with interesting solutions to improve propeller efficiency and added fuel efficiency.

5.4.2 Technological Interventions[16]

The development thrust and expenditure of the various five-year plans of the government with regard to marine fisheries has been towards marine capture fisheries. To enhance the production of marine fish, the focus has been towards developing technologies that helped in harvesting fish. The institutional efforts have been geared towards improving craft and gear and therefore, this is considered the most important technological intervention contributing to improvement in production.

5.4.2.1 Improvement of Craft

Introduction of mechanised fishing and motorisation of country craft are significant interventions that have boosted marine fish production in India. Mechanised craft are power driven fishing craft fitted with inboard engines (50-120 HP) while motorised country craft are fitted with outboard engines (less than 50 HP; 2-9 HP is common). Mechanised fishing is generally large scale while motorised fishing is small scale. Mechanised craft are divided into two categories: craft that are capable of fishing in deep waters (500 metre depth and above) and for 10-15 days, called multi-day fishing vessels, and small trawlers that fish in near shore waters (50-100 metre depth). The former generally have all electronic fish finding devices and on-board ice storage facilities. The motorised fishing units use gill nets; craft sizes are also increasing, ranging between 40 and 50 feet in overall length.

Initially, the non-mechanised sector was the only sector in existence. Indian fishermen used the age-old craft and gear evolved centuries ago. The Government of Mumbai made the first attempt to introduce trawling in India in 1900 by using a steam trawler. But intensive efforts to develop the fisheries sector started only after 1947, i.e., in the post-Independence period. In 1953, the Indo-Norwegian Project attempted mechanisation of the existing traditional craft along the Kerala coast, but it was unsuccessful. In 1954, INP started concentrating on developing new designs. The first 22-feet boats with a 4 HP semi diesel engines built between 1956 and 1958 did not find much acceptance as the craft showed no outright superiority over traditional ones nor were there adequate landing facilities available. In 1958 INP introduced a 25-feet boat with 8-10 HP full diesel engine, capable of using larger quantities of traditional gear as well as fishing at greater distances. This was followed by a 23.5 feet craft with an 8-10 HP diesel engine in 1961, which yielded better results than the 25-feet craft. In 1962, a new 25-feet boat with 16 HP diesel engines capable of using a small shrimp trawl was introduced. In the mid and late 1950s, some State governments commenced mechanisation with the collaboration and assistance of FAO and INP.

[16] This section is based on discussions we have had with experts in this field as well as on our survey of literature. Some of the experts we consulted are Dr.S.Ayyappan, DDG (Fisheries), ICAR, Professor P.Selvaraj, retired professor at FCRI, Thoothukkudi, and scientists at CMFRI. We have drawn heavily from the following sources: CMFRI (2003) and Pillai and Katiha (2004).

Diversified methods of fishing such as purse seining and pole and line fishing were popularised. Although the operational aspects of purse seining trials were reported to be a good venture, it was not successful as the purse seine catches consisted mainly of small pelagic fishes (www.ifpkochi.nic.in).

During the period 1963–1979, CIFT developed 12 standard designs capable of trawling as well as other kinds of fishing such as hand lining, gill netting and purse seining, with suitable modification in deck layout. CIFT also developed cheaper and suitable boat building materials as well as engine designs for better performance (www.cift.nic.in).

Efforts to motorise traditional craft began as early as 1953 in Jaleshwar village, Gujarat but it did not make much headway in other parts of India. In the late 1970s keen competition from shrimp trawlers in the inshore waters spurred many traditional fishermen, especially along the southwest coast of India, to motorise their fishing craft to expand their fishing area. In the 1980s, the Bay of Bengal Programme introduced modified versions of beach landing craft; in 1985 the craft type IND-25 became a suitable model to be operated along the Andhra Pradesh and Orissa coasts (www.bobp.org).

5.4.2.2 Improvement in Fishing Gear

The advent of synthetic fibres was a landmark in the development of fishing gear in the country. The manufacture of multifilament nylon yarn (polyamide group of fibres) in India was started only in 1962. In 1977, manufacture of polyethylene and nylon monofilaments for making fishing nets began. Today, twisted netting yarns and braided netting yarns of different sizes are available in the country and virtually the entire fisheries sector uses only synthetic fibres for gear. The combination rope of polyethylene and polypropylene (Danline) and polyamide monofilament is being extensively used as an import substitute for tuna and shark long lines. Fishing hooks and snood wires of international standards are also available in the market, which are either made by small scale industrial units or through technical collaboration with foreign manufacturers.

Another technology that has become highly popular among traditional fishermen, especially along the southwest coast of India, is the new CIFT-designed lobster trap, which is a rod frame mounted with square welded mesh coated with plastic to prevent corrosion. Earlier, fishermen were catching lobsters using traditional traps made of easily biodegradable vegetable fibres that lasted only for 2-3 weeks. In comparison, the new traps are 2.5 times more efficient than the traditional traps in terms of catches and also last for 3-4 fishing seasons (Devadasan 2002).

The high opening bottom trawling method for demersal fishery was a major technological breakthrough introduced in 1982 by BOBP along the Tamil Nadu coast and in 1983 by CIFNET along the Gujarat coast. In 1999, medium-sized trawlers used in shrimp fishing along the Kerala coast were upgraded and fitted with GPS and echo sounders. Trawling has emerged as the most important method for exploiting demersal fishery resources. Trawlers have become the mainstay of the fishing sector and 50 % of the total Indian catch comes from trawlers (Bhathal 2004). During the late 1990s, the fishing industry undertook deck modifications in their shrimp trawlers so as to carry out drift gill netting targeting high value fishes (Balasubramaniam 2000).

5.4.3 Measures of Impact of Craft and Gear Improvement

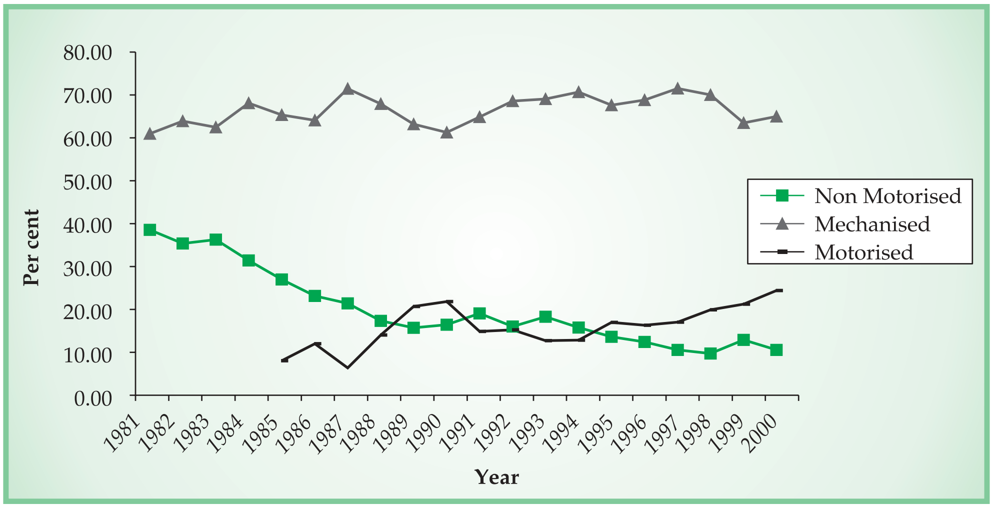
Fisheries production in India during the 1950s was largely from marine fish landings. Marine fisheries landings increased more than five-fold over the five decades from 1951–52 to 2001–02, growing from 0.5 million tonnes to 2.9 million tonnes. Marine fish landings can be from motorised / mechanised craft as well as non-motorised craft. Over the years the importance of non-motorised craft in the marine fisheries sector has been declining.

Figure 5.8: Marine Fish Landings

Source: Ministry of Agriculture (2004); Jhingran (1991)

In the early 1960s, almost the entire landings were by using traditional craft and gear. In 1981 the landings from this sector accounted only for 40 per cent of total landings (0.52 lakh tonnes) and it further declined to 10 per cent (0.23 lakh tonnes) by 2000. With the introduction of mechanisation and motorisation of country craft, the contribution from the non-motorised artisanal sector has been gradually dwindling (Srinath 2003).

Figure 5.9: Contribution to Total Landings by Different Types of Craft



Source: Srinath (2003)

Figure 5.9 indicates that over the 20 years from 1981 to 2000, the contribution through mechanised craft remained in the range of 60 to 70 %. The share of motorised craft gradually increased from 10 % to 30 %

over the period 1985 to 2000. By 2000, the mechanised sector had emerged as the single largest contributor of the total marine fishery landings in India, accounting for nearly two-thirds of the total production. From 1.8 lakh tonnes in 1969 it increased to 17.9 lakh tonnes in the year 2000, with a peak landing of 19.4 lakh tonnes in 1997. The share of the mechanised sector increased from 20 % in 1969 to 67 % during the year 2000 (Srinath et.al 2003). The amount of time expended for actual fishing by this sector has almost doubled during the last fifteen years, rising from about 17.4 million hours during 1986 to 33.5 million hours during the year 2000. This has been mainly due to the introduction and increase in voyage fishing activities in all the maritime States of India. Motorisation of country craft has been one of the significant technological interventions that have facilitated easy mobility, faster access to the fishing grounds, and the ability to venture into deeper grounds. This process has had significant impact on marine fishery, supplemented by introduction of efficient gear such as the ring seines. The landings by the motorised craft increased from about 1.28 lakh tonnes in 1985 to 6.81 lakh tonnes in 2000 (Srinath 2003).

An analysis of the total factor productivity of the marine sector in India indicates that over the period 1987 to 1998, input index has moved 25 points while the output index has moved 83 points and the growth of total factor productivity is 2.01 %. The analysis indicates the positive impact of technology on productivity (Kumar 2004).

The harvestable potential of marine fishery resources in the Exclusive Economic Zone (EEZ) has been estimated to be around 3.921 million tonnes. An estimation of depth-wise potential shows that about 58 % of the resources are available at 0-50 m depth, 35 % at 50-200 m depth and 7 % at depth beyond 200 m.

Table 5.11: Estimates of Potential Resources and Levels of Exploitation in EEZ, 2000-01

(million tonnes)

Item	Depth range (m)			Oceanic	Total
	0-50	50-200	200-500		
Potential resources	2.28 (58.1)	1.367 (34.9)	0.028 (0.7)	0.246 (6.3)	3.921 (100.0)
Present level of exploitation	2.08	0.82	Negligible	Negligible	2.9
Available for exploitation	0.20	0.547	0.028	0.246	1.021

Note: Figures in brackets are the percentages to total potential resources.
Source: Ministry of Agriculture (2004)

The Fishery Survey of India (FSI) has been responsible for surveys and assessment of the marine fishery potential of the Indian EEZ. The maximum sustainable yield (MSY) of the fish stocks has been assessed as 3.9 million tonnes, which include demersal (2.01 million tonnes), pelagic (1.67 million tonnes) and oceanic (0.3 million tonnes) resources (Somvanshi 2003). The density of fish is highest at about 11 tonnes per sq. km in coastal areas (0-50 m), and in waters beyond 50m, it is less than 1 tonne per sq. km.

Table 5.12: Extent of Exploitation in Indian EEZ, 1977 to 2001

Resources	1977	1987	1990	1996	2001
Potential in 0-200 m depth (million tonnes)	3.88	3.59	3.67	3.64	3.64
Level of exploitation (million tonnes)	1.25	1.64	2.30	2.71	2.90
Percentage of exploitation	32.2	45.7	62.7	74.5	79.7

Source: Jhingran (1991) and Ministry of Agriculture (2000, 2004)

Table 5.12 indicates that the exploitation percentage has doubled over the period from 1977 to 2001. The most important characteristic of marine capture fisheries is that the resources are common property, the access to which is free and open. The Central Marine Fisheries Research Institute has conducted surveys, including census of fishermen and craft and gear, in the years 1961–62, 1973–77, 1980, 1993 and 1998.

Table 5.13: Manpower and Fleet Size in Marine Fisheries, India

Item	1961-62	1973-77	1980	1993	1998
Active fishermen (in lakhs)	2.3	3.2	4.7	8.0	10.0
Motorised	----	-----	-----	26,171	50,922
Non-motorised	90,424	1,06,480	1,40,833	1,55,925	76,596
Mechanised		8,086	19,013	34,571	49,070
Trawlers	-----	-----	11316	-----	30,979

Source: Srinath (2003)

The increase in number of active fishermen implies less fishing area per fisher. In an open access system, crowding of fishers leads to competition and increased conflicts, resulting in an overall depletion of the resources.

Table 5.13 depicts that there has been very high growth in the number of motorised and mechanised craft. Motorisation started in the early 1980s in Maharashtra and Gujarat. Later, it was initiated in all the maritime States, most extensively in Kerala. The keen competition from trawlers in the inshore waters prompted many traditional fishermen to adopt motorisation of craft to expand their fishing grounds. Over the period 1993 to 1998, there has been a drastic reduction in the non-motorised fleet. Simultaneously, the declining resources and increasing fuel costs compelled many traditional fishermen to prefer installation of outboard motors rather than adopt mechanised boats. Until 1966, marine diesel engines were imported but by 1977 there were about 9 manufacturers of the same in the country with a capacity to produce engines of even 10,000 HP (Korakandy 1994).

By the year 1998 nearly one million active fishermen were engaged in marine fishing in India, of which about 0.2 million were active in the mechanised sector, 0.17 million in the motorised sector, and the rest in the artisanal sector. Among those engaged in the mechanised sector, 75 % worked in trawl fisheries and 25 % in the fisheries operating gill nets, bag (dol) nets, purse seines and deep-sea vessels. In the case of the motorised sector, 60 % were engaged in ring seine fishery alone, which is predominant on the southwest coast and rest in various other forms. In the artisanal sector, of the total 0.63 million active fishermen, 41 % were engaged in the operation of catamarans, 31 % in plank built boats, and the rest in dug-out canoes and others. (Devaraj et al. 1998)

Table 5.14: Area per Boat, India

(in ha)

1961-62		1973-77		1980		1990	
Inshore	Offshore	Inshore	Offshore	Inshore	Offshore	Inshore	Offshore
(0-50m)	(50-200m)	(0-50m)	(50-200m)	(0-50m)	(50-200m)	(0-50m)	(50-200m)
7106	11852	2877	4156	1843	2868	1189	1801

Note: Excluding Andamans and Lakshadweep area

Source: CMFRI (1997)

Table 5.14 shows that with increase in the number of boats for inshore and offshore over the years, area per boat has declined drastically. However, over the 1980s area per boat with respect to offshore fishing has increased indicating a decline in boats in offshore fisheries in 1990 compared to 1980.

Analysing data on catch trends for two time periods — 1985–89 and 1995–99 — shows that the contribution percentage of commercially important groups such as crustaceans and cephalopods have increased to a considerable extent. The cephalopods level of exploitation shows that it was being overexploited during 1995–99 as the average catch accounted to 1.05 lakh tonnes, which is above the estimated potential yield of 1.01 lakh tonnes.

Table 5.15: Catch Trends of Different Marine Fish Groups, India

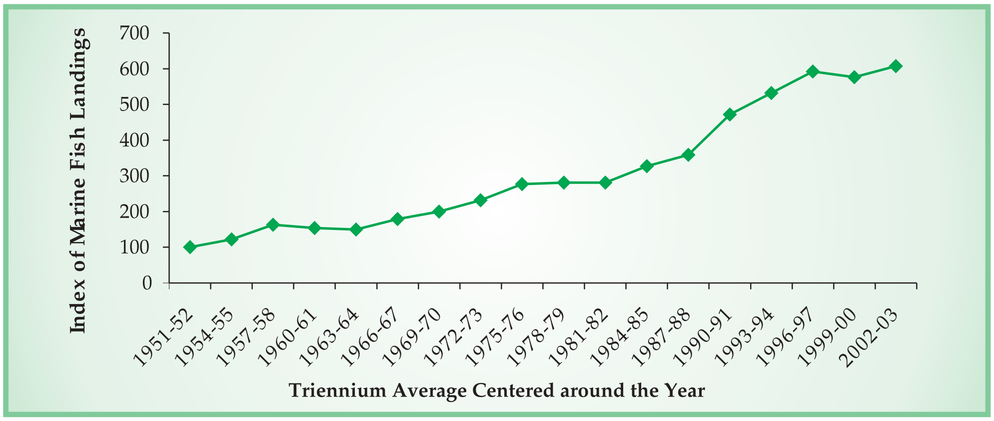
Group	Average catch (t)		Estimated Potential yield (t)
	1985-89	1995-99	
Pelagic resources	8,95,425 (56.0)	11,63,844 (46.0)	16,08,233
Demersal resources	4,31,725 (27.0)	5,90,567 (23.5)	7,92,203
Crustaceans	1,91,130 (12.0)	3,96,519 (15.7)	4,57,128
Cephalopods	39,799 (2.5)	1,05,883 (4.2)	1,01,259
Others	40,034 (2.5)	2,67,135 (10.6)	9,75,594
Total	15,98,113 (100.0)	25,23,948 (100.0)	39,34,417

Note: Figures in parentheses indicate percentage to the total; t refers to tonnes.
Source: Modified from Pillai and Katiha (2004)

5.4.3.1 Technology Achievement Index: Marine Fisheries

As in the case of carp production, an index for technology achievement in the marine fisheries sector has been worked out using landings (production from marine source) as an indicator. Given that data is available for this indicator since 1950–51, the technology achievement index has been computed for the period 1950–51 to 2002–03. Using the triennium average of marine production for the years 1950–51 to 1952–53 as the base, the index has risen from a base of 100 to 607 in triennium 2000–01 to 2003–04.

Figure 5.10: Technology Achievement Index: Marine Fisheries



Source: Jhingran (1991) and Ministry of Agriculture (various years)

5.4.4 Concluding Observations

One of the major objectives of the Indian Government has been to achieve food security and the five-year plans have been used as a major instrument towards this. Increasing fish production in the country has been part of this larger agenda of attaining food security and a number of steps has been taken for the development of fisheries in the country. These programmes are briefly listed in **Table 5.16**.

In recognition of the increasing role of inland fisheries in overall fish production, the Government of India has been implementing two important programmes in the inland freshwater sector since the Fourth Five Year Plan. These are the Fish Farmers Development Agencies (FFDA) and the National Programme for Fish Seed Development (NPFSD). By 2003–04 a network of about 429 FFDAs covered all potential districts in the country. This network covered about 6.49 lakh ha of the total water area under scientific fish culture and trained 7.61 lakh fish farmers. Under NPFSD, improvement in fish seed production has increased from less than 8000 million fry in 1986–87 to about 17,000 million fry in 2000–01.

Table 5.16 Developmental Thrust during Various Five-Year Plan Periods

Plan	Period	Development Thrust
I	1951-55	Inland fisheries- collection of spawn and fry from natural resources; legislation passed in some States for bringing neglected water under fish culture. Marine Fisheries: Introduction of mechanised fishing vessels and modern gear materials.
II	1956-61	Programmes initiated in the First Plan continued during the Second Plan with added thrust on development of marine fisheries; Infrastructure for preservation, processing, storage and transportation introduced.
III	1961-66	Thrust on increased fish production, mechanisation of fishing vessels and programmes on improvement in the condition of fishermen; Schemes on development of infrastructure for landing and berthing facilities for facilities for fishing vessels introduced.
IV	1969-74	Development of export potential, including setting up of an autonomous authority for export promotion; Allocation of separate outlay for fisheries research; Setting up of Special Trawler Development Fund; Setting up of Fish Farmers' Development Agencies and Fish Seed Development to promote inland aquaculture.
V	1974-79	Development of brackish water fisheries, survey of marine fisheries resources, development of infrastructure facilities for coastal fishing villages, etc. Motorisation of artisanal craft and introduction of purse seines in 1977, declaration of EEZ.
VI	1980-84	Assistance for acquisition of trawlers for deeper fishing; Development of inland fisheries statistics; Establishment of prawn hatcheries and prawn farming; Promulgation of Maritime Act.
VII	1985-90	Motorisation of traditional fishing craft; National welfare fund for development of fishermen villages; Conservation of marine resources through closed seasons; Initiation of new deep sea fishing policy.
VIII	1992-96	Strengthening of inland fish marketing, resource enhancement through artificial reefs; Fisheries training and extension; Setting up of large number of minor fishing harbours and fish landing centres; Setting up of Aquaculture Authority for regulation of shrimp farming.
IX	1997-2002	Acquisition of survey vessels for strengthening Fishery Survey of India; Modernisation of fishing harbours and fish landing centres; Installation of artificial reefs / fish aggregating devices.
X	2002-07	Development of domestic fish marketing network, oceanic fisheries, sea ranching and cage culture.

Source: www.planningcommission.nic.in

Being basically a small-scale enterprise, freshwater aquaculture provides for the domestic food security of rural India. The traditional carp culture technology received an impetus with scientific support in the 1970s. Since then carp production has contributed a major share to inland fish production, increasing from 34 % in 1986 to 65 % in 2000. To promote carp production with adequate seed availability, hatchery production of seeds by induced breeding was also developed. The most important impact of the enormous effort of the public sector research activities pertaining to freshwater aquaculture is the rapid increase in aquaculture carp production: in 1986, carp production was of the order of 4.18 lakh tonnes and by 2000 it reached a level of 18.8 lakh tonnes, a more than four-fold increase in less than 15 years. This rapid increase is essentially related to the improvement in yield levels brought about by the adoption of composite fish culture technology where the different layers of the pond ecosystem are effectively utilised. Open water bodies are not used to the optimum, only 26% of the available resource potential has been exploited in 2003.

The strategies included in the development of marine fisheries as envisaged in the five-year plans are described below.

First phase 1950–1965

- tapping the vast potential of marine fisheries through mechanisation of craft
- providing adequate landing and berthing facilities to fishing vessels by construction of major and minor fishing harbours and landing centres
- intensifying efforts on processing, storage and transportation

Second phase 1965–1980

- declaration of Exclusive Economic Zones (EEZ)
- intensive fishery resource assessment surveys in EEZ
- establishment of landing and berthing facilities
- promotion of export marine fishery products
- motorisation of fishing craft

Third phase 1980–2000

- introduction of deep sea trawlers
- promulgation of Maritime Act (1981)
- erection of Fish Aggregating Devices (FADs)
- improving marketing through co-operative sectors

The major developments include construction of 30 minor fishing harbours and 130 fish landing centres apart from the five major fishing harbours at Cochin, Chennai, Visakhapattinam, Roychowk and Paradeep to facilitate landing and berthing of fishing craft.

During the past five decades, the Indian marine fisheries sector has transformed from a traditional, subsistence avocation into a market-driven multicrore industrial sector. Marine fish production has increased through successive stages, first with a change from natural to synthetic fibres in gear fabrication, introduction of mechanised craft, introduction of trawl nets and, mainly, motorisation of fishing craft. The developments in inland fisheries and marine fisheries over the years have paved the way for what is hailed as the ***Blue Revolution*** or ***Aquaplosion*** in India. The Blue Revolution has resulted in an increase in per capita availability of fish in the country over the last 15 years as is clear from **Table 5.17**.

Table 5.17: Per capita Fish Availability in India

Year	Per capita aquaculture carp availability kg/annum	Per capita inland fish availability kg/annum	Per capita marine fish availability kg/annum	Per capita fish availability kg/annum (inland + marine)
1986	0.54 (100)	1.59 (100)	2.22 (100)	3.82 (100)
1987	0.62 (115)	1.65 (104)	2.10 (95)	3.76 (98)
1988	0.69 (128)	1.66 (104)	2.26 (102)	3.92 (103)
1989	0.76 (141)	1.71 (108)	2.77 (125)	4.47 (117)
1990	0.75 (139)	1.83 (115)	2.74 (123)	4.57 (120)
1991	0.89 (165)	2.00 (126)	2.86 (129)	4.86 (127)
1992	1.03 (191)	2.05 (129)	2.95 (133)	5.01 (131)
1993	1.17 (217)	2.24 (141)	2.97 (134)	5.21 (136)
1994	1.17 (217)	2.30 (145)	2.96 (133)	5.26 (138)
1995	1.30 (241)	2.42 (152)	2.92 (132)	5.33 (140)
1996	1.54 (285)	2.52 (158)	3.14 (141)	5.65 (148)
1997	1.62 (300)	2.53 (159)	3.06 (138)	5.59 (146)
1998	1.58 (293)	2.61 (164)	2.74 (123)	5.39 (141)
1999	1.71 (317)	2.82 (177)	2.85 (128)	5.67 (148)
2000	1.85 (343)	2.79 (175)	2.76 (124)	5.55 (145)

Note 1: The population data given in National Accounts Statistics of India 1950-51 to 2002-03 published by Economic and Political Weekly Research Foundation was used to calculate per capita availability.

2: It is important to note that the above data refers to whole fish and not dressed ones.

3: Figures in brackets indicate the index w.r. to year 1986.

Source: Ministry of Agriculture (various years), EPW Research Foundation (2004).

Due to the technological interventions and proper institutional support, the per capita fish availability has gradually increased from 3.82 kg / annum in 1986 to 5.55 kg / annum in 2000.

REFERENCES

Ayyappan. S and J.K.Jena. 2001. "Suitable Freshwater Aquaculture in India". In Pandian (ed) *Sustainable Indian Fisheries.* New Delhi: National Academy of Agricultural Sciences.

Balasubramaniam. 2000. "Modifications of Craft and Gear in Diversified Tuna Fishery Undertaking at Tharuvaikulam, Gulf Of Mannar, India". *Marine Fisheries Information Service, T & E Series.*, 164: 19-24.

Bhathal, Brajgeet. 2004. *Historical Reconstruction of Indian Marine Fisheries Catches, 1950-2000, as Basis for Testing the "Marine Trophic Index"*. Graduate thesis, The University of British Columbia.

Chaudhuri, H., and K.H. Alikunhi. 1957. "Observations on the Spawning in Indian Carp by Spawning Injection". *Current Science,* Vol.No.12.

Devadasan, K. 2002. *Commercially Viable Fishery-Based Technologies Recently Developed by CIFT.* CIFT Technology Advisory Series 10. Kochi: Agricultural Technology Information Centre, Central Institute of Fisheries Technology.

Devaraj, M., V. S. R. Murty, R. Sathiadhas and K. K. Joshi. 1998. "The New Economic Policy and Perspectives for Marine Fisheries Research and Development in India". *Fishing Chimes,* 18 (5).

Economic and Political Weekly Research Foundation. 2004. *National Account Statistics of India 1950-51 to 2002-03*. Fifth Edition. Mumbai.

FAO: 1990, 1995, 2000. *Aquaculture Production Statistics*. Rome.

Indian Council of Agricultural Research. 2006. *HandBook of Fisheries and Aquaculture.* New Delhi.

Jhingran, V.G. 1991. *Fish and Fisheries of India.* Delhi: Hindustan Publishing Corporation.

Khan. 1938. "Ovulation in Fish (Effect of Administration of Anterior Lobe of Pituitary Gland)". *Current Science.* 7 (5):233-34. Cited in Jhingran.

Korakandy, Ramakrishnan. 1994. *Technological Change and the Development of Marine Fishing Industry in India.* New Delhi: Daya Publishing House.

Kumar, Praduman. 2004. *Fish Demand and Supply Projections in India: Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia.* Project sponsored by Asian Development Bank. New Delhi: Division of Agriculture Economics, Indian Agricultural Research Institute.

Ministry of Agriculture (Department of Animal Husbandry and Dairying and Fisheries). 1991, 1996, 2000, 2004. *Handbook of Fisheries Statistics.* New Delhi: Government of India.

Murty, V.S (ed). 1997. *Vision – 2020 CMFRI Perspective Plan*. Kochi: Central Marine Fisheries Research Institute.

Planning Commission. 2001. *Report of the Working Group on Fisheries for the Tenth Five Year Plan*. New Delhi: Government of India.

Pillai, N.G.K., and P.K. Katiha. 2003. *Aquaculture Technologies and Fishing Practice in India: Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in India.* Asian Development Bank Sponsored Indian Council of Agriculture Research- World Fish Centre Project, Final Report. (Unpublished)

———. 2004. *Evolution of Fisheries and Aquaculture in India.* Kochi: Central Marine Fisheries Research Institute.

Saha, G.S. 2002. *Technological Innovations in Aquaculture and its Effects on Sustainability of Farming Systems in Andhra Pradesh.* ICAR funded Project Report. (Unpublished)

Sinha, V.R.P. 1999. *Rural Aquaculture in India.* Publication No.1999/21, Rome: FAO.

Srinath, M. 2003. “An Appraisal of the Exploited Marine Fishery Resources of India”. In Mohan Joseph and JayaPrakash (eds.) *Status of Exploited Marine Fishery Resources of India.*Kochi: Central Marine Fisheries Research Institute.

Srinath, M. Somy Kuriakose, K.G.Mini, M.R.Beena and Sindhu K.Augustine. 2003. “Trends in Landings”. In Mohan Joseph and Jayaprakash (eds.) *Status of Exploited Marine Fishery Resources of India.*

Srivastava, U.K., Bakul H. Dholakia, S. Sreenivas Rao and S. Vathsala. 1993. *Freshwater Aquaculture in India.* New Delhi: Oxford and IBH Publishing Co. Pvt.Ltd.

Somvanshi, V.S. 2003. “Indian Experience on Assessment, Measurement and Monitoring of Fishery Resources and Fishing Capacity”. In Pascoe and Gréboval (eds.) *Measuring Capacity in Fisheries.* Fisheries Technical Paper No. 445. Rome: FAO.

www.bobp.org

www.cift.nic.in

www.cmfri.nic.in

www.dahd.nic.in

www.ifpkochi.nic.in

www.planningcommission.nic.in

www.wikipedia.org

6

FORESTRY*

6.1 Introduction

Forests, the main body of the terrestrial ecological system, are a complete resource base as well as habitat. Forests comprise several interactive subsystems that are part of a complex biological organisation that performs multiple overlapping and interfacing roles and functions. In India, forestry accounts for the second largest land use, after agriculture. For a significant section of the Indian population, forests are the main source for sustaining livelihoods. Half of India's tribal peoples, one of the most disadvantaged sections of Indian society, subsist on forest resources. Forests also serve as grazing ground for livestock. Apart from meeting the material requirements of people and livestock, forests play an important role with regard to ecology and environment.

Scientific management of forests is the basic underlying principle of sustainable forestry. Sustainable management of forests is necessary for the continuous production of goods and services. Goods from forests command a price in the markets while services from forests, social or ecological, are intangible non-transferable products and are distinct from physical commodities. Unlike goods, services are not separate entities over which ownership rights can be established and they cannot be traded separately. Environmental services resulting from, or enhanced by, conservation of resources also represent production, as are the material products resulting from resource management. The productivity theme is thus crucial to forestry as an enterprise, science and profession (Duerr 1981). All forestry contributions (goods and services, direct and indirect benefits) have socio-economic significance for society at the local as well as at the national level. Ecological / environmental contributions of forests have global significance too. Some of the potential benefits of forests, as carbon sinks and reservoirs of bio-diversity, are only being recognised in recent times. However, at the same time as one gets to know more about the potential contributions of forests, more of them are disappearing due to deforestation and forest degradation. Sustainable management of forests is thus considerably complex, given the multiplicity of forest products and benefits (including their use values and non-use values), as well as the conflicts caused among stakeholders and various interest groups. Particular features of forestry, namely, its long gestation period and investment horizon (often not matching with the social time preference), the difficulty to distinguish between forest capital and incremental growth (often leading to overexploitation and capital consumption), and the high level of externalities further add to its complexity (John Joseph 2005). The basic concern of forestry is to maintain and develop forest resources in such a way that a sustainable output of forest products and services is guaranteed. The purpose of forestry science is to establish a systematic and logical knowledge base for such endeavours. Ideally, forestry science should concentrate on aspects relating to 'natural' factors as well as 'social and economic' factors (Van Viet 1987).

Scientific forestry has been practised in India over the last 150 years.[1] Independent India has been committed to conserving her forest resources, and suitable policies have been evolved and adopted with

*Contributed by Dr. S. John Joseph, Former Principal Chief Conservator of Forests, Tamil Nadu.

[1] India had a forest policy even as early as 1894.

regard to the protection of forests. However, India's forests suffered large-scale extraction and deforestation due to the two World Wars and the rapid rise in the country's population has subsequently contributed to the increasing pressure on forests.

The evolution of silvicultural systems for the sustainable management of forests and the formulation of wood preservative ASCU can be considered major scientific research and development inputs in the past. The Forest Research Institute (FRI) was established in Dehra Dun in 1906 with the objective of making provision for scientific research in forestry. The Forest Research Institute was reconstituted with its functions extending over all of India, with branches dealing with silviculture, forest management, forest zoology, forest botany, forest chemistry and forest economy. In 1956, the Government of India took over the regional laboratory set up at Bangalore by the former Mysore State government and reconstituted it as a regional centre of FRI, Dehra Dun. The approach of this institution was confined to timber products and their utilisation. In 1988, forest research in India was re-organised and the Indian Council of Forestry Research and Education (ICFRE) was set up in Dehra Dun as an umbrella organisation with eight institutions and three centres situated in different agro-ecological sectors under it.[2] The functions and focus of these institutions recognised the role of forests in ecological balance, environmental stability, biodiversity conservation, food security and sustainable development.

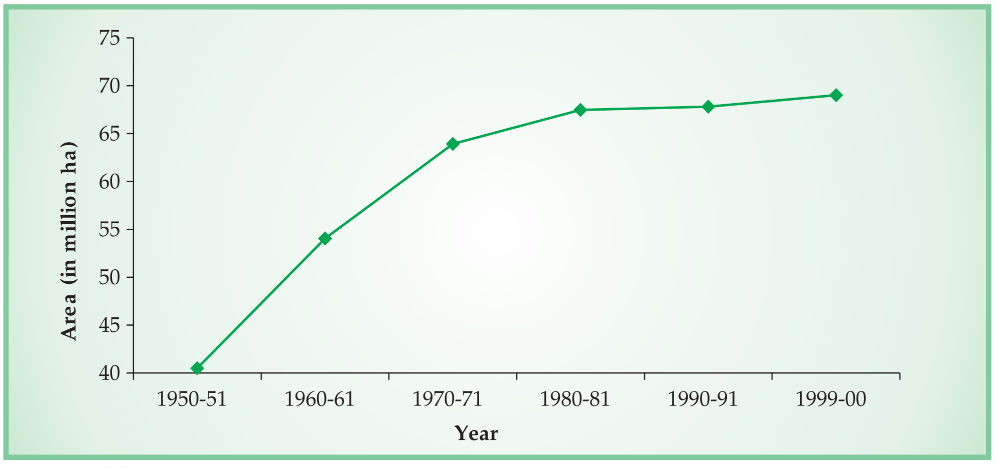
Consequent to various measures taken by the state, the area under forests has registered an increase over the decades since 1950–51. **Table 6.1** and **Figure 6.1** provide data on area under forests in India.

Table 6.1: Area under Forests in India

Land use	1950-51	1960-61	1970-71	1980-81	1990-91	1999-2000
Area under forests (in million ha)	40.48 (14.2)	54.05 (18.1)	63.91 (21.0)	67.47 (22.2)	67.80 (22.2)	69.02 (22.6)

Note: Figure in brackets give the percentage of geographical area under forests.
Source: Agriculture Statistics at a Glance (2003)

Figure 6.1: Area under Forests in India



Source: Table 6.1

[2] Forest Research Institute, Dehra Dun; Himalayan Forest Research Institute, Shimla; Tropical Forest Research Institute, Jabalpur; Institute of Wood Science and Technology, Bangalore; Institute of Forest Genetics and Tree Breeding, Coimbatore; Arid Forest Research Institute, Jodhpur; Rain Forest Research Institute, Jorhat; Institute of Forest Productivity, Ranchi; Centre for Social Forestry and Eco-Rehabilitation, Allahabad; Centre for Resource Development, Chhindwara; Forest Research Centre, Hyderabad

Improvement in the area under forests in recent years in India is largely due to interventions in the aspects of conservation and management of the fast dwindling natural forest, protection of endangered flora and fauna, wildlife management and development of high yielding plantations.

This chapter attempts to analyse the impact of science and technology on the forestry sector, covering constituents such as conservation forestry, restoration forestry, production forestry, wildlife management, protection forestry, and research and utilisation forestry. In addition to the government's commitment of large areas for conservation in pristine natural forest condition, aided by appropriate policies, technological interventions have also promoted the various dimensions of forestry in India. However, the peculiarity and complexity of forestry (as compared to the other sectors discussed in this report) makes it difficult to understand and evaluate the impact of technology in forestry. Therefore, the attempt here is only to discuss the major technological interventions in the field of forestry in India. Given the difficulty in assessing the goods and services flowing to the nation because of forestry and given that the benefits of forestry are not solely related to technological interventions, there has been no computation of an index of technological achievement.

6.2 Management Science in Forestry

The application of satellite technology as a tool has led to a significant appreciation of the realities and status of the forest ecosystem, thereby bringing about drastic changes in management approach and strategy.

Based on the National Forest Policy of 1952 laying emphasis on forest survey and demarcation, the Pre-Investment Survey of Forest Resources (PISFR) was started as a joint project with the United Nations Development Programme (UNDP) and the Food and Agricultural Organization (FAO). Realising its strategic role and the importance of collection of data at national level, PISFR was converted into the Forest Survey of India (FSI) in 1981. The primary objective of FSI is the periodic assessment of the country's forest resources. **Table 6.2** depicts the data collected in nine assessments.

Space-borne remote sensing technology has proved to be an important tool in the rapid assessment and mapping of natural resources over large areas with reasonable accuracy. Application of satellite data in assessment of forest cover[3] in India was first demonstrated by the National Remote Sensing Agency (NRSA) of the Department of Space, Hyderabad in 1985, with the first ever estimate of the country's forest cover carried out based on interpretation of Landsat (an American satellite) data. Almost simultaneously, the Forest Survey of India started interpreting satellite data for assessment of the forest cover of the country and published a report in 1987 using Landsat (MSS) data. Thereafter, FSI was mandated to assess and map the forest cover of the country using satellite data on a two-year cycle. There has been rapid development in satellite-based technology and also in related high end hardware and software for digital image processing of satellite data. FSI has kept pace with these developments by continuously updating its methodology.

[3] All tree canopies that can be delineated and assessed from satellite data (sensor LISS III of IRS satellite 1C/1D) is termed as forest cover; a tract of land, recognized as forest if it is legally proclaimed to be a forest under the forest law (Indian Forest Act of 1927 or the relevant State Forest Act) and recorded/notified as forest in government records, is termed as area under forests.

Table 6.2: Satellite Data of Forest Cover, India

Assessment No/ year		Data period	Sensor	Data form	Spatial resolution	Scale of interpretation	Forest cover in km²***
I	1987	1981-83	Landsat - MSS	Hard Copy FCC	80m	1:1 million	6,40,819 (19.49%)
II	1989	1985-87	Landsat - TM	Hard Copy FCC	30m	1:250,000	6,38,804 (19.43%)
III	1991	1987-89	Landsat - TM	Hard Copy FCC	30m	1:250,000	6,39,364 (19.45%)
IV	1993	1989-91	Landsat - TM	Hard Copy FCC	30m	1:250,000	6,39,386 (19.45%)
V	1995	1991-93	IRS-1B LISS II	Hard Copy FCC and Digital *	36.25m	1:250,000	6,38,879 (19.43%)
VI	1997	1993-95	IRS-1B LISS II	Hard Copy FCC and Digital **	23.5m	1:250,000	6,33,397 (19.27%)
VII	1999	1996-98	IRS-1C / ID LISS III	Hard Copy FCC and Digital **	23.5m	1:250,000	6,37,293 (19.39%)
VIII	2001	2000	IRS-1C / ID LISS III	Digital	23.5m	1:50,000	6,75,538 (20.55%)
IX	2003	2002	IRS-ID LISS III	Digital	23.5m	1:50,000	6,78,833 (20.64%)

Note: 1. Figures in brackets in last column are percentages to geographic area;

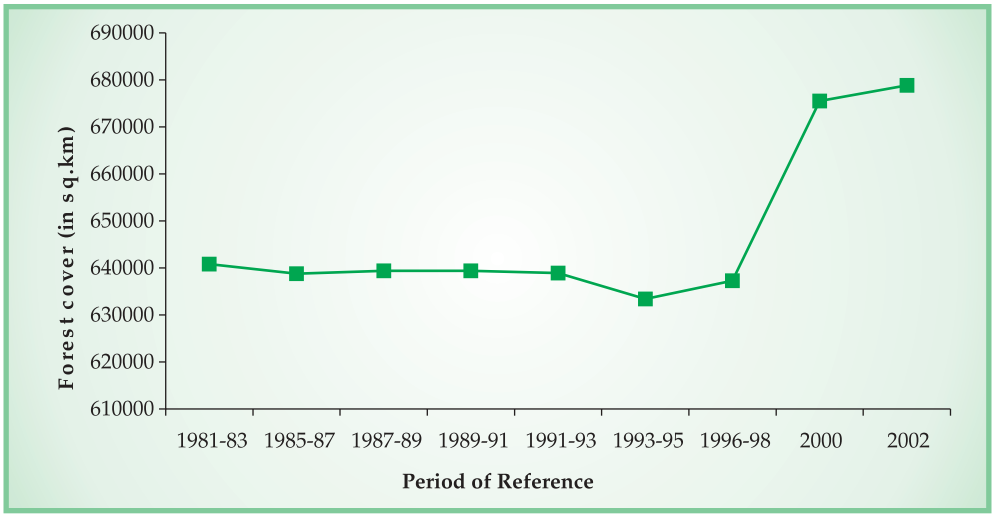
2. * Digital Data used for two states; ** Digital Data used for 14 states; *** Revised figures of forest cover from 1989 to 1995 are given after incorporation of interpretational corrections.

3. MSS- MultiSpectral Scanner; TM- Thematic Mapper; IRS- Indian Remote Sensing Satellite; LISS- Linear Imaging and Self Scanning Sensor.

Source: Forest Survey of India (2003)

The results of the nine assessments show that the forest cover in the country had declined from 19.49 % to 19.27 % in the period 1981–83 to 1993–95. That is, the country lost 0.74 million hectare of forest cover over a period of 12 years. However, from 1993–95 to 2002, the forest cover in the country showed an upward trend and the percentage of area increased from 19.27 % to 20.64 %. The technological improvement in the quality of data as well as the imaging software has led to more accurate assessment of the forest cover and also the scale of maps has increased to the present 1:50000 scale. Minimum mappable area (cartographic limit) of the assessment has improved from 400 ha in 1987 assessment to 1 hectare in 2000–02.

Figure 6.2: Forest Cover in India



Source: Table 6.2

The National Forest Policy of 1952, laying emphasis on the conservation and preservation of forests, prescribed that at least one-third of the total geographical area of the country should be under forests. Per capita forest in India is estimated to be the lowest among the Asian countries.[4]

Given that one-third of India's geographical area is not under forests, and that the per capita availability of forests is also relatively low, it is imperative that the available forest resources of the country are maintained in a sustainable manner.

The assessment of forest area indicates only the land under forest cover. The assessment of the growing stock of forest is more important for the appreciation and understanding of the quality and potential of forests as a productive system that ensures flow of tangible goods and other ecological services on a sustainable basis. For the first time, FSI estimated the growing stock of Indian forest in 1995. FSI's assessment of growing stock was based on vegetation maps, thematic maps and ground forest inventory. By dividing the whole country into 1,70,000 grids, FSI provided inventory data on growing stock and forest composition in terms of 21 species Strata. This exercise also yielded three density classifications on the basis of crown density i.e. more than 70 percent, between 40-70 % and between 10-40 %. Area of forest having less than 10 % crown density is treated as scrub.[5]

Forests can be managed by adopting two basic systems of management, which occupy two ends of a spectrum. The simple and easiest is the clear felling of forests and converting the area into plantations of

[4] In 1995, per capita availability of forests was 0.08 ha in India as against 1.62 in Malaysia (www.faostat.org).

[5] The technology for measuring tree density is simple in the digital mode. In a satellite frame depicting forest area, the percentage of ground cover occupied by crown projection on the ground is worked out on an area occupation basis and expressed as a percentage of the area under consideration.

select tree species having marketability and commercial demand e.g., teak and eucalyptus. At the other end of the spectrum is the selection system of forest management, which is also considered a natural forest management system (upgraded to a fine art in German forestry). In this system, only trees attaining maturity are felled in a selective manner on a sustainable yield basis. Here, natural regeneration is induced and reared by various subsidiary silvicultural operations (John Joseph 2005).

Management of tropical forests is necessary for a variety of purposes: timber for industrial needs, forest products for rural communities, watersheds for multipurpose use, and land use alterations based on land capability and / or conservation. Depending upon the objectives, the approach to management could differ considerably. Timber extraction could be based on conversion of selected tree species into plantation forests or by management of natural forests of selected tree species or by management of natural forests through selective extraction and natural / induced regeneration for sustained yield. Much of the forest area in the Indian sub-continent and 2-3 % of cut-over forest elsewhere are under some cutting regime or other, followed by silvicultural treatment and protection. Starting from 1864 when systematic natural management practices began in India, the emphasis has been on extraction of better-known high quality timber species. With the decline in the availability of timber, a few better-known commercial species (non-traditional) were also harvested along with smaller biomass. With a low annual average productivity level of 0.5-1 cubic metre per hectare, productivity is indeed very low compared to the much higher global average (Kaushik 1969). Added to this is the problem of very poor or even total absence of natural regeneration in more than 50 % of natural forests (FSI 2003).The chief obstacle to natural forest management is the low rate of return on investment. Lack of silvicultural knowledge, human population pressure, overgrazing by animals, illicit felling, etc., are also identified as factors obstructing natural forest management (Ramakrishnan 1993).

The Bhopal-India Process, developed by the Indian Institute of Forest Management, Bhopal, is a practical and indigenous mechanism for monitoring sustainable forest management in the country. Criteria and indicators (C&I), compatible with international and regional initiatives, have been developed after thorough deliberations and discussions involving ecologists, foresters, scientists and academicians, for the purpose. These criteria are applicable both locally (at the management unit) and at policy levels (the national level). At the international level, FAO and the International Union of Forestry Research (IUFRO) have validated the Bhopal-India Process.

Table 6.3: Criteria and Indicators, Bhopal-India Process

	Criteria	Indicators
1.	Increase in the extent of forest and tree cover	Area and type of forest cover under natural forest and man-made forest; Tree cover outside forest area; Area of dense and open forest; Forest area diverted for non-forestry use; Extent of community-managed forest areas
2.	Maintenance, conservation and enhancement of bio-diversity	Area of protected eco-systems; Area of fragmented eco-systems; Number of rare, endangered, threatened and endemic species; Level of species richness, and bio-diversity in selected areas; Availability of medicinal and aromatic plants in various forests types; Status of non-destructive harvest of NWFP; Numbers of keystone and flagship species in various forest types
3.	Maintenance and enhancement of ecosystem function and vitality	Status of natural regeneration; Status of secondary forests; Incidences of: pest and diseases; Weed infestation; Grazing and fire
4.	Conservation and maintenance of soil and water resources	Area under watershed treatment; Soil erosion status; Area under ravines, saline and alkaline soils, mining, sand dunes; Groundwater table in the vicinity of forest areas
5.	Maintenance and enhancement of forest resource productivity	Growing stock of wood; Volume of production of identified / important NWFPs; Increment of volume of identified species of wood; Level of financial investment in forestry sector; Extent of area under seed production, seedling seed orchard, clonal seed; orchards and clonal plantations
6.	Optimisation of forest resource utilisation	Aggregate and per capita consumption of wood and NWFP; Import and export of wood and NWFP; Recorded production of wood and NWFPs;Direct employment in forestry and forest industries; Contribution of forests to the income of forest dependent people; Level of processing and value addition in NWFPs and treatment, seasoning and preservation of wood;.Demand and supply ratio of timber, firewood and fodder
7.	Maintenance and enhancement of social, cultural and spiritual benefits	Degree of people's participation: Number of committee and area(s) protected by them; Use of indigenous technical knowledge: identification, documentation & application; Quality and extent to which rights and privileges are utilised; Human development index; Extent of cultural / sacred -protected landscapes: forests, trees, ponds, streams, etc.

Note: NWFP = non-wood forest produce

Source: Kotwal et al (2002)

The traditional management approach to forests is sought to be streamlined and systematised by this refining process. The indicators having a bearing on each criteria are assessed and examined annually by the executive divisions in an administrative process known as Control Operation.

6.3 Strategic Interventions in the Forestry Sector

6.3.1 Conservation Forestry

Conservation forestry refers to management of forestry in such a manner that it yields the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations. The global community's commitment towards conservation and sustainable use of biodiversity is ensured by the Convention on Biodiversity passed in the United Nations Conference on Environment and Development in 1992. India owes its unique biodiversity to the bio-geographic and environmental diversity it possesses. Over 75,000 species of fauna and 47,000 species of flora are found in India (FSI, 1992). Crop species that have originated from forests number 166. Forests have high species diversity and endemism. Pressure on this diversity is immense as judged from forest loss and fragmentation. Red Data Books have been published by the Botanical Survey of India under the Project on Study, Survey and Conservation of Endangered Species of Flora (POSSCESF). The total number of threatened plant taxa in all categories is 1,331, which represents 8% of the flora. (Nayar and Sastry (eds) 1987, 1988, 1990). It is thus necessary to have suitable interventions to conserve biodiversity. Proper assessments are essential for effective conservation of biodiversity. For rapid biodiversity assessment, Geographic Information System (GIS) approaches were used and FSI has undertaken the interpretation of remote sensing maps using International Union for Conservation for Nature and Natural Resources (IUCN) criteria. Benchmark sites were identified and information was generated on each agro-climatic zone through the initiatives of the National Forestry Action Plan (NFAP), Botanical Survey of India (BSI), Zoological Survey of India (ZSI) and World Wide Fund for Nature (WWF).

In India, *ex situ* and *in situ* conservation methods have been adopted to conserve biodiversity. *Ex situ* conservation is in the form of gene pool gardens, botanical gardens and arboretums. Considering that some rare and endangered species are on the verge of extinction, their germplasm is conserved and preserved either in the form of seeds in gene banks or as live specimens in field gene banks, botanical gardens or arboretums (exclusively for trees). As against the technology for conserving rare and endangered species in gardens and external locations by artificial means, *in situ* conservation is a step to conserve them in their own habitat in nature. Taxonomic combing helps to identify the existence and availability of such species in natural locations. *In situ* conservation is practised by promoting the following:

a) National parks, sanctuaries, conservation reserves, community reserves under the Wildlife Amended Act, 2002

b) Biodiversity heritage sites under the Biological Diversity Act, 2002

c) Community conserved area under state / centre or customary law

d) Hotspots (areas rich in biodiversity and endemism)

e) Biosphere reserves and Ramsar sites

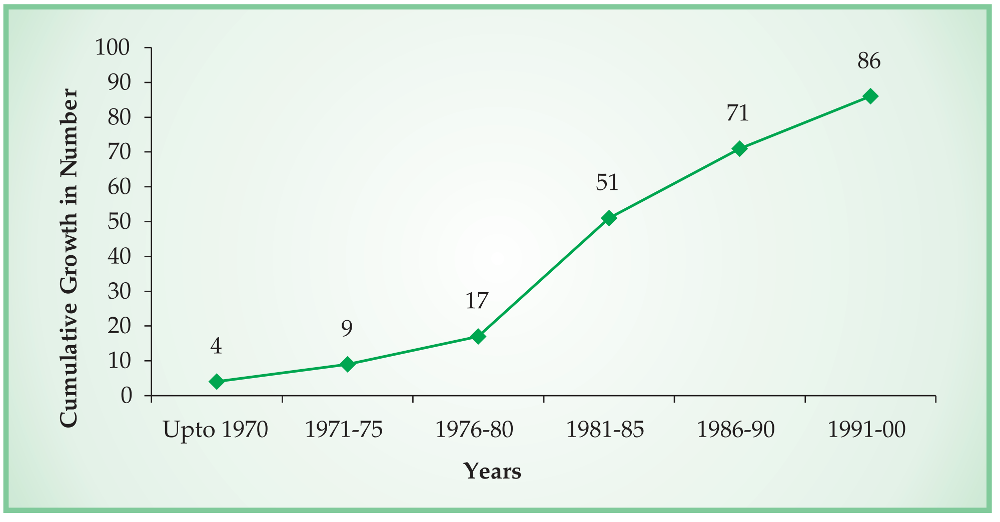
The creation of protected areas started in 1936 with the establishment of the Corbett National Park in the foothills of Himalayas. The number of national parks and wildlife sanctuaries has since grown rapidly with the setting up of the Indian Board for Wildlife in 1952 and the enactment of the Wildlife Protection Act in 1972. As of 2000, there are 86 national parks and 480 wildlife sanctuaries covering about 14 % of Indian land area. As can be seen from **Figures 6.3, 6.4** and **6.5,** a large number of national parks and wild life sanctuaries have been constituted over three decades, starting with the 1970s. The entire protected area, comprising national parks and wildlife sanctuaries, is spread across the 10 bio-geographic zones of the country.

Table 6.4: Some Biosphere Reserves in India

Sl. No.	Name of the site	Area (sq.km)	Location
1	Nilgiris	5520.00	Part of Wayanad, Nagarhole, Bandipur and Mudumalai, Nilambur, Silent Valley and Siruvani Hills
2.	Nanda Devi	5860.69	Part of Chamoli, Pithoragarh and Almora Districts (Uttaranchal)
3.	Nokrek	820.00	Part of Garo Hills (Meghalaya)
4.	Manas	2837.00	Part of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamrup and Darang Districts (Assam)
5.	Sunderbans	9630.00	Part of the delta of the Ganges and Brahmaputra river system (West Bengal)
6.	Gulf of Mannar	10,500.00	Indian part of Gulf of Mannar between India and Sri Lanka (Tamil Nadu)
7.	Great Nicobar	885.00	Southernmost islands of Andaman and Nicobar Islands
8.	Similipal	4374.00	Part of Mayurbhanj district (Orissa)
9.	Dibru-Salkhowa	765.00	Part of Dibrugarh and Tinsukia districts (Assam)
10.	Dehand Debang	5112.00	Part of Siang and Debang valley in Arunachal Pradesh
11.	Pachmarhi	4926.28	Part of Betual, Hosangabad and Chindwara districts of Madhya Pradesh
12.	Kanchenjunga	2619.92	Parts of Kanchenjunga Hills in Sikkim
13.	Agastyamalai	1701.00	Neyyar, Peppara and Shenduruny wildlife Sanctuaries and their adjoining areas in Kerala

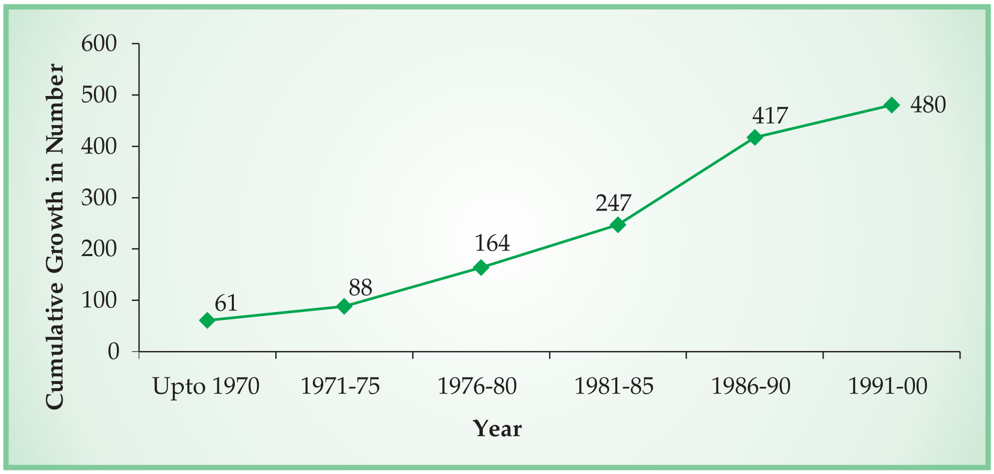
Source: http://en.wikipedia.org/wiki/List_of_Biosphere_Reserves_in_India

Figure 6.3: Number of National Parks in India



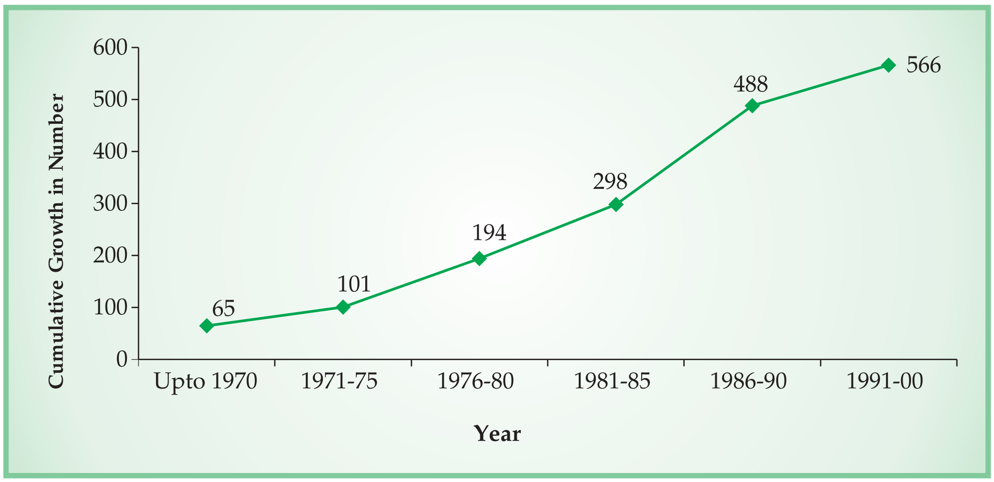
Source: ICFRE Forestry Statistics India (various years)

Figure 6.4: Number of Wildlife Sanctuaries in India



Source: ICFRE Forestry Statistics India (various years)

Figure 6.5: Number of Protected Area in India



Source: ICFRE Forestry Statistics India (various years)

Apart from the initiatives taken by the government, there are also community-based interventions that conserve biodiversity. India has a long history of nature worship and areas designated for this purpose are termed sacred groves. Sacred groves are dedicated to local deities or ancestral spirits and are protected by local communities through social traditions and taboos that incorporate spatial and ecological values. Trees and plants are allowed to grow undisturbed in the sacred groves and therefore reptiles, birds and animals live here without fear of interference by man. These have become veritable storehouses of medicinal plants as well as biodiversity treasure-houses. The number of sacred groves in various parts of India and in *in situ* conservation areas is estimated to be around 84,000 (Israel Oliver King 2005).

Local level initiatives undertaken by non-governmental organisations (NGOs) have also contributed towards conservation. The Foundation for Revitalisation of Local Health Traditions (FRLHT), an NGO based in Bangalore, has been involved in the *in situ* conservation of medicinal plants in Tamil Nadu, Karnataka and Kerala. FRLHT has established medicinal plant conservation areas (MPCAs) to capture the maximum possible diversity of medicinal plant taxa in comparatively undisturbed forests across the three southern states. In all, 34 MPCAs have been established, with areas ranging from 80 to 685 ha, with an average area of 217 ha. While MPCAs have captured 41 to 63 per cent of medicinal plants diversity in the three project states, they have not been able to secure viable breeding populations of medicinal plants. Therefore it has been decided that these MPCAs should be the nuclei for promoting *in situ* conservation of medicinal plants, to be treated as restricted areas with no harvesting of medicinal plants allowed except for research purposes. Four MPCAs have been located specifically for capturing significant populations of medicinal plant species of very high conservation concern: Kollur in Karnataka for *Saraca asoca*, Kulamavu in Kerala for *Coscinium fenestratum*, Anapady in Kerala for *Utleria salicifolia*, and Nambikovil in Tamil Nadu for *Janakia arayalpathra*. These MPCA are also rich in total species diversity due to favourable site and climatic conditions.

6.3.2 Restoration Forestry

Restoration forestry refers to the efforts taken to restore an ecosystem to its original structure. In this section, a major programme of the Government of India towards restoration of forests, namely, Joint Forest Management (JFM) is discussed. A case study of Mangrove Rehabilitation Programme undertaken by the M.S. Swaminathan Research Foundation (MSSRF) is also analysed.

6.3.2.1 Joint Forest Management

It is a well documented fact that during the Second World War as well as in recent years forests have been subjected to use and abuse, much beyond their carrying capacity. An assessment made by FAO on the extent of natural forest cover in the country indicates that in year 1900, forest cover accounted for 27 % of land in India and this has declined sharply over the years to 15 % by 2000.[6] It is estimated that if this trend continues, forest cover in India will further decline to 12 % by 2050 (FAO 1996). A study carried out by the National Remote Sensing Agency in 1980 has confirmed the widespread deforestation in the country. Further, substantial area under forests is also degraded. Demand for timber and fuelwood from forests in India is estimated to exceed the production capacity of forests (Singh 2005).

Taking into consideration the widespread deforestation and degradation of forests, a community-based management approach termed Joint Forest Management has been set up to promote the sustainable use of forests. The National Forest Policy of 1988 envisaged people's involvement, particularly of women, in meeting their basic forest-related needs and in managing their local resources. In 1990 the Ministry of Environment and Forests issued guidelines for the involvement of village communities and voluntary agencies in the regeneration of degraded forests. The Joint Forest Management Programme seeks to develop partnerships between local community institutions and state forest departments for sustainable management and joint benefit sharing of public forestlands.[7] The primary objective of JFM is to ensure sustainable use of forests to meet local needs equitably while ensuring environmental sustainability. The

[6] This refers to natural forest cover excluding plantations and area under shifting cultivation

[7] JFM was initiated in 1972 as an experiment in West Bengal by the pioneering efforts of Dr.A.K. Banerjee, the young forest officer who launched a most innovative socio-economic project in a cluster of 11 villages in the Arabari block of Midnapore district. The approach involved eliciting the support of local villagers in the protection of forests as well as the plantation of a few select species through the formation of Forest Protection Committees (FPC) in return for free usufructs of all NWFP. Altogether 618 families participated in the project protecting 1272 ha of forest land. Based on the overwhelming success of the Arabari experiment, JFM programme gradually spread to neighbouring areas and received increasing support.

central premise is that local women and men who are dependent on forests have the greatest stake in sustainable forest management (Extension Digest 1999).

During the last 15 years the JFM movement has witnessed a phenomenal growth. Twenty-two States have undertaken concrete measures to create local institutions for protection and management of forests. The nature of usufructs sharing varies from State to State. Women's representation is mandatory in the constitution of committees. As of 2001, about 36,130 forest protection committees were managing a total of 10.25 million ha of forest area. By 2005, nearly all the States had adopted JFM and more than 65,000 forest protection committees have been formed.

Tamil Nadu has embarked on a massive watershed-based JFM programme to restore the more than 7000 sq. km of forests that are in various stages of degradation. About 3000 villages skirting these forests are badly affected by devastation of environmental security. The Tamil Nadu afforestation project, conceptualizing a blend of forest development, watershed development and rural development, envisages restoration of 3.5 lakh ha of degraded forests abutting 1000 interface villages, over a five-year period (Sreedharan 2002).

Table 6.5: JFM Phase I Achievements, Tamil Nadu, 2002

Afforestation of degraded forests	4.80 lakh hectares
Number of village forest committees formed	1367
Number of self-help groups formed	3891
Water table rise	10-20 % (despite drought)
Technology thrust	GIS application; Range offices computerised
Employment	1,75,000 forest-dependent people provided alternate employment

Source: Government of Tamil Nadu (2006)

A study was conducted by the internal monitoring unit of the Tamil Nadu Afforestation Programme-JFM Project to assess the impact of the intervention on the ecological, hydrological, and socio-economic status of the affected forests. An internal evaluation was undertaken during 1997–98 to 1999–2000 in 60 randomly selected JFM areas spread over the entire State. Ecological impact was assessed through the indicators of tree density, diversity of species, status of wildlife and the degree of survival of artificial regeneration in forest areas. The changes observed in tree density are shown in **Table 6.6**.

Table 6.6: Changes in Tree Density, Tamil Nadu

Year of regeneration area	No. of sample plots observed	Tree Density			Average Height			
		Prior to JFM intervention No. of trees	After JFM intervention No. of trees	Percentage of increase	Prior to JFM inter-vention (m)	After JFM inter-vention (m)	Percentage of increase	Period of obser-vation
1997-1998	151	2,274	3,652	60	1.68	2.30	37	3 years
1998-1999	354	7,995	11,179	39	1.80	2.12	18	2 years
1999-2000	359	5,623	8,748	50	2.10	2.57	22	1 year

Source: Government of Tamil Nadu (2006)

It is evident from **Table 6.6** that tree density has increased. There is 60 % increase of tree density in 1997–98 regeneration areas, which proves that with the increase in years of protection there is a proportional upgradation in the status of degraded forests. Similarly, the average growth of height of trees has recorded an increase of 37 % in 1997–98 in regeneration areas, which again proves the effect of protection in the growth of tree stock.

The health of forests depends a lot on the floristic composition and species diversity. Trees are in the top order of floristic composition of bio-diversity and hence are very important indicators. **Table 6.7** highlights the species diversity in tree regeneration.

Table 6.7: Species Diversity in Tree Regeneration, Tamil Nadu

Year	Number of sample plots observed	Average number of species observed per sample plot at baseline	Average number of species observed per sample plot 1999-2000	Percentage of increase in species diversity	Period under observation (Year)
1997-98	151	11	14	27	3
1998-99	354	14	19	36	2
1999-2000	359	14	17	21	1

Source: Government of Tamil Nadu (2006); Sreedharan (2002)

Natural regeneration of degraded forests is best achieved by effective social fencing. There is a good rate of survival in the regeneration areas in spite of poor site conditions in the degraded forests. Elimination of biotic pressure and extensive soil and moisture conservation have contributed to the better survival rates of seedlings.

Degraded Forest – Tirunelveli District, Tamil Nadu, 2000

After regeneration by JFM in 2005

6.3.2.2 Technological Innovation in Mangrove Rehabilitation

According to FSI, out of 4.7 hectares of mangrove wetlands in India nearly 58 % are in the east coast, and the rest is divided equally between the west coast and the Andaman and Nicobar islands.

Table 6.8: Mangrove Forests in India (1992)

State	Mangrove Forest	Actual forest area (in ha)
West Bengal	Sunderbans	2,12,500
Orissa	Mahanadi	21,500
Andhra Pradesh	Godavari	24,100
	Krishna	15,600
Tamil Nadu	Pichavaram	900
	Muthupettai	1,855
Gujarat	Gulf of Kutchh	85,400
	Gulf of Combay	17,700
Andaman and Nicobar islands	Andaman	92,900
	Nicobar	3,700
Total		**4,76,155**

Source: Selvam et al. (undated)

In 1992, a survey conducted by the Ministry of Environment and Forests (MoEF) in various mangrove wetlands in India concluded that most of the mangroves were in a highly degraded condition because of changes in physical structure due to past unscientific management practices and reduction in fresh water flow. An ecological study conducted by the MSSRF team found that coupe felled areas of mangrove change from being flat to trough-shaped. Seawater gets locked in the troughs, causing high salinity and consequent failure of young crops as well as regeneration. MSSRF developed a simple technique to restore the degraded areas: a canal system consisting of main and feeder canals was designed and dug in the degraded areas. The main canals were connected to natural canals nearby. This enabled tidal water to flow freely in and out of the degraded area (instead of stagnating), thus decreasing salinity and increasing soil moisture. Planting mangrove saplings completed the task of restoration.

MSSRF successfully demonstrated this technique in the Pichavaram mangrove wetlands between 1993 and 1996. This simple technique was also demonstrated in a degraded land of 10 ha belonging to the forest department. The Tamil Nadu Forest Department (TNFD) and MoEF evaluated this technique as the best available method to restore degraded mangroves and it has been included in the National Mangrove Management Plan. Consequent to this, five States have launched major programmes of rehabilitation of mangroves based on this technique, and the results are promising.

6.3.3 Production Forestry

The most important technological intervention in the field of production forestry has been the development of clonal technology.

6.3.3.1 Clonal Technology: Genetic improvement of *Casurina equisetifolia*

Traditionally, eucalyptus plantations are raised mainly through seedlings of *E.teretecornis* and *E.camaltulensis*. In order to increase the yield per unit area, clonal forestry in eucalyptus through the shoot-cutting method (macro propagation technique) was launched. A genetic improvement programme was initiated in the late 1970s by introducing fresh germplasm of a wide genetic base of eucalyptus from Australia. Both long-term and short-term strategies were used for improving the yield from plantations. Rapid genetic improvements in eucalyptus were made through macro and micro propagation methods. In plantations raised through seeds, the variability was high, resulting in low yields, while in clonal forestry the yield was much higher. The mean recorded yield of eucalyptus plantation per ha in a rotation of 7 years was about 20 tonnes.

A twenty-year breeding programme was formulated in Andhra Pradesh in 1994 in collaboration with the Institute of Forest Genetics and Tree Breeding, Coimbatore (IFGTB). Three unrelated sublines with 100 trees each were formed with selections from superior trees selected from Andhra Pradesh and adjacent states, and also from IFGTB. The tested clones were converted into Clonal Breeding Orchards with the restricted breeding of different sublines of Clonal Breeding Orchards and they were grouped in Clonal Seed Orchards and new infusions were made during progeny tests at every generation (Maheswar Rao et al 2001). From these seedlings, seed orchards were established and outstanding clones were used for mass multiplication in clonal forestry programmes.

Table 6.9: Seed Production Areas, Clonal Seed Orchards, Seedling Seed Orchards

Item	Location	Species	Area committed (ha)
Seed Production Areas (SPA)	In 16 states in 200 locations	All species of commercial value, wood & NWFP	8513.37
Clonal Seeds Orchards (CSO)	Madhya Pradesh, Maharashtra, Nagaland, Orissa, Rajasthan, Sikkim, Tamil Nadu	Teak, Sisco, Eucalyptus, Casuarina, Cashew, Neem, Bluegum, Tamarind, Pine, Khair, Gmelina, Bombax	1398.64
Seedling Seed Orchards (SSO)	Andhra Pradesh, Goa, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Tamil Nadu, Uttar Pradesh, West Bengal	All important and commercial species, (indigenous and exotic)	2668.00
Institutions Involved ICFRE Institution, FRI, IFGTB, TFRI, IFP, IWST, AFRI, IRMDFR, HFRI, CSFER.	—	Teak, Sisco, Eucalyptus, Casuarina, Pine, Khair, Gmelina, Poplars, Rosewood, Alder, Sandal, Terminalia, Dipterocarp	SPA - 1300.60 CSO - 1670.00 SSO - 324.40

Source: ICFRE Forestry Statistics India (2001)

Good work has been done in clonal forestry by ITC Bhadrachalam, J.K. Paper Mills, and Tamil Nadu Forest Plantation Corporation (TAFCORN). TAFCORN has used clonal plants for the planting programme from 2000–2001 onwards. It has established clonal plantations of up to 1500 hectares with superior eucalyptus clones (Government of Tamil Nadu 2006). This technology ensures equally high yields and production in the second rotation crop also and does not require replanting and fresh investment other than management. Up to 2005, J.K. Paper Mills has supplied 1 million clonal plants and ITC Bhadrachalam Industries Limited has supplied 5 million clonal plants to farmers.

ITC has been a pioneer in the application and transfer of clonal technology to farmers. As early as 1991, it established two clonal demonstrations in Bhadrachalam based on five short-listed clones with outstanding performance. Clonal saplings of test clones with productivity ranging from 20-58 m^3 per ha per year under non-irrigated conditions were released to farmers on a selection basis from 1992 for developing farm forestry plantations. Clones with high productivity, resistant to pests and diseases, and drought tolerant were short-listed and multiplied on a large scale, and distributed to farmers.

From 1992 to 2001, 14 million clonal saplings have been supplied by ITC to farmers, bringing 8000 ha under clonal plantation (Kulkarni 2002). Factors that have favoured the adoption of clonal plantations are economic profitability, demand for industrial wood, buy-back guarantee of the company, climatic and edaphic conditions (low rainfall, poor irrigational facilities), uncertainty and frequent failure of agriculture, and attraction toward non-agricultural works (Piare Lal and Kulkarni 1993).

6.3.3.2 Other Interventions

Forests in India have always been a major source for industrial wood as well as fuelwood for households. Available data for the years 1949–50 to 1970–71 show that annual wood production, which reflects the demand for wood, was growing over the 20 years. Production of industrial wood was growing at the rate of 4.42 % per annum since 1950–51, while that of fuelwood was at less than 1 per cent and overall wood production was growing at 1.86 % over the same period.

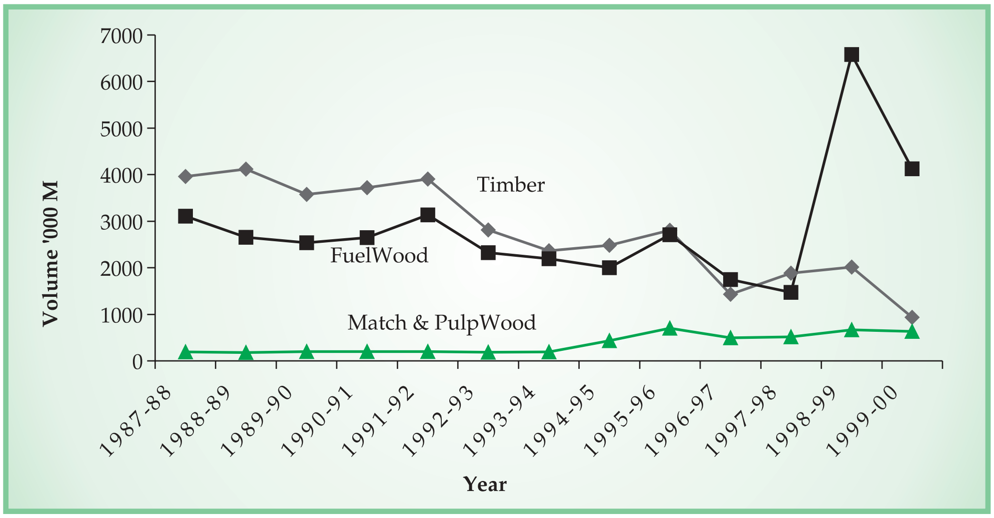
Table 6.10: Total Annual Wood Production, 1949-50 to 1970-71

Year	Industrial Wood million cu.m.	Fuelwood million cu.m.	Total Wood million cu.m.	Index of total wood 1961-62 =100
1949-50	3.79	11.35	15.14	92
1950-51	3.84	11.95	15.79	95
1951-52	3.98	10.71	14.69	89
1952-53	3.25	9.45	12.70	77
1953-54	3.06	9.32	12.38	75
1954-55	3.83	10.70	14.53	88
1955-56	4.16	10.81	14.97	91
1956-57	4.46	10.18	14.64	89
1957-58	4.67	10.98	15.65	94
1958-59	4.70	11.96	16.66	101
1959-60	5.57	11.68	17.25	105
1960-61	5.43	11.64	17.07	104
1961-62	5.59	10.87	16.46	100
1962-63	7.61	13.16	20.77	126
1963-64	7.15	12.49	19.64	119
1964-65	6.45	12.77	19.22	117
1965-66	8.61	13.10	21.71	131
1966-67	9.28	12.24	21.52	130
1967-68	9.57	13.11	22.68	138
1968-69	9.37	11.59	20.96	127
1969-70	8.93	12.86	21.79	132
1970-71	9.12	13.69	22.81	139

Source: Mathur (1976)

If the demand for wood had continued to grow after the 1970s at the same rate as in the1960s, it would have led to the overexploitation of forest resources. Given that forests are to be protected not only for the resources that are derived from them but also for their role with regard to ecology, it becomes imperative to adopt a forest management practice that deals with larger issues of sustainability of forests while simultaneously concentrating on enhancing wood production. In the case of forestry, growing stock forms part of the capital and therefore programmes such as social forestry and agro forestry have been launched.

Figure 6.6: Production Trend of Different Forest Produce, 1987-2000



Source: FAO Statistics; www.faostat.org

Figure 6.6 indicates a decline in timber harvesting over the 1990s with a simultaneous increase in production of pulpwood and fuelwood. This trend is related to the implementation of programmes such as social forestry and agro forestry across the country.

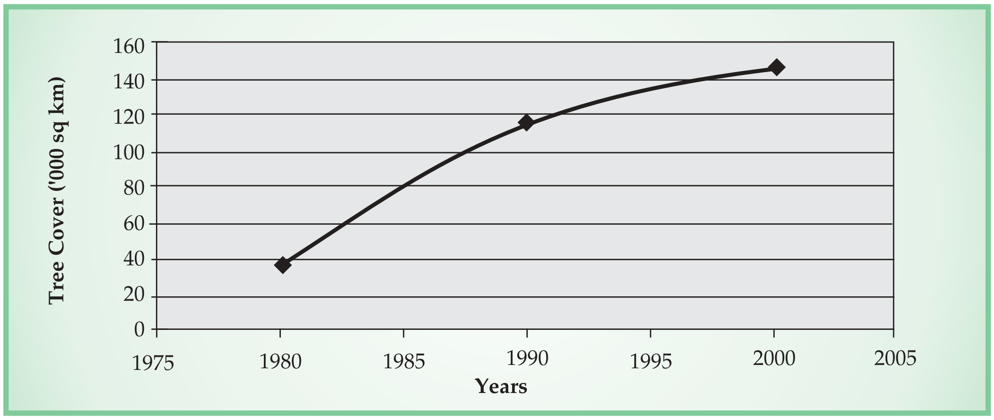
Social forestry attempts to grow trees on new sites — village lands and private lands — to meet the demand for fuelwood and small timber. Forestlands were still to be used for production of commercial timber, while production outside reserved forests was encouraged to meet the other demands of people. Social forestry programmes aimed to reclaim potentially productive wastelands by raising tree crops in areas available along roads, railways and canals in the country (John Joseph 2005). In the mid 1980s, the area under social forestry plantations in the country was about 8.8 million hectares and it increased to nearly 14.8 million hectares by the mid 1990s (Poyry 2004).

Agro-forestry refers to trees on lands (rural and urban) outside the recorded forest areas.

On account of the large demand for wood in industries, as well as the desired quality of material required for various end uses, the dependence on natural principles of reproduction has to give place to man-made forests like plantations. This conversion essentially implies replacing species-rich natural ecosystems by species-poor monoculture of trees. The teak (*Tectona grandis*) and sal (*Shorea robusta*) plantations in India are examples of such conversion. The introduction of fast-growing species is required to provide for maximum volume production, and a considerable area has been planted with different species in different parts of the country. Poplars have become the most important among tree species, constituting man-made forests in the irrigated tracts of the upper Indo-Gangetic plains. WIMCO Seedlings Limited has contributed significantly towards poplar-based agro forestry that feeds into their matchwood production (Chandra 2001).

FSI has been conducting an inventory of tree cover outside forests since 1991. **Figure 6.7** is based on data compiled from 180 districts on a sampling basis and indicates a clear upward trend in tree cover outside forests over time (FAO / FSI 2004).

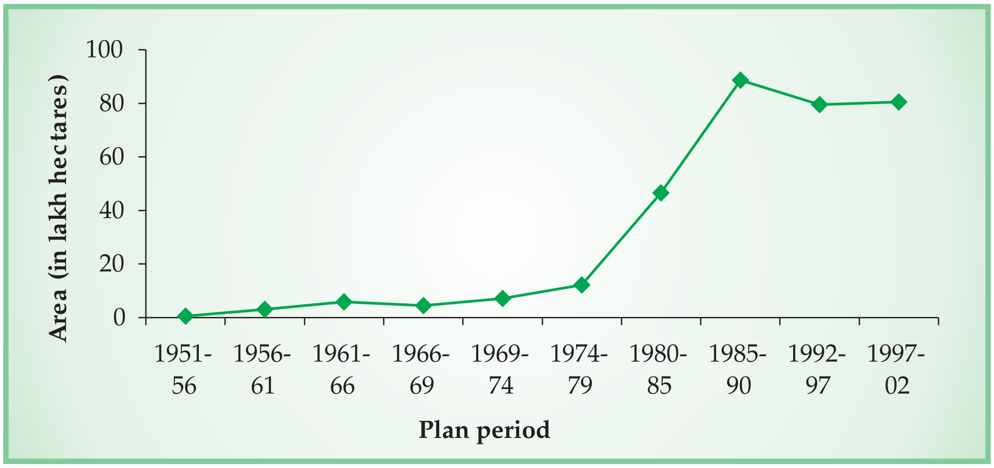
Figure 6.7: Tree Cover outside Forests



Source: FAO / FSI (2004)

India's achievements in raising forest plantations, in terms of area, has been impressive: up to 2002, the total area of tree plantations under different schemes was 36.21 million ha; of this, 3.54 million ha were raised before 1980 and 13.51 million ha during the 1980s and the rest after 1990. Generally, fast-growing tropical pines or eucalyptus have been preferred for plantations. It is said that where exotic species such as eucalyptus are involved, the sustainability criterion becomes critical and it is necessary to evaluate the ecological and economic effects.

Figure 6.8: Area Afforested during Five Year Plan Periods



Source: ICFRE Forestry Statistics India (2003)

Forests produce a host of non-wood produce such as leaves, seeds, nuts, fruits, herbs, resin, gum, etc. In the central forests of India, bidi leaf extraction is the major NWFP, providing employment and income to the tribal population. Realising the importance of NWFP, the Ninth Five Year Plan (1997–2002) has formulated a major scheme to augment the production of these resources by artificial introduction of species of trees and plants in forests found in a depleted condition.

Figure 6.11: Production of Non-Wood Forest Produce, 1987–2000

(000 mt)

Products	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
Sal seeds	21.29	23.81	54.58	-	-	-	-	18.53	27.62	87.51	12.58	57.78	78.74
Bidi leaves	505.53	531.50	556.04	-	-	-	-	542.76	322.16	112.25	744.35	384.94	400.81
Canes	1.61	6.26	42.60	-	-	-	-	65.14	345.38	5.02	2.10	18.69	2.02
Resin	98.32	105.59	117.59	-	-	-	-	88.23	169.24	26.02	18.34	14.35	0.96
Gums	13.82	4.09	1.39	-	-	-	-	21.10	3.04	3.56	1.00	2.14	2.42
Lac	9.11	68.97	1.06	5.77	6.01	8.28	7.28	9.07	0.10	0.08	0.75	0.02	0.31
Drugs & Spices	12.05	11.49	18.66	26.53	62.81	23.33	18.16	21.57	59.78	41.21	62.7	-	-
Grass & Fodder	304.49	332.47	119.98	1,021.95	161.79	421.62	113.34	74.91	64.06	62.98	418.53	213.85	45.78
Tanning material	20.22	234.00	22.40	20.27	20.42	8.39	11.52	10.46	8.35	19.06	4.93	-	-
Others	318.44	229.70	68.58	-	-	-	-	10,039.27	7,782.12	111.91	197.94	69.94	165.95
Bamboo	642.38	829.76	1,934.59	660.12	754.64	721.34	455.40	822.63	632.54	1,186.05	3,629.79	1,119.67	1,261.86

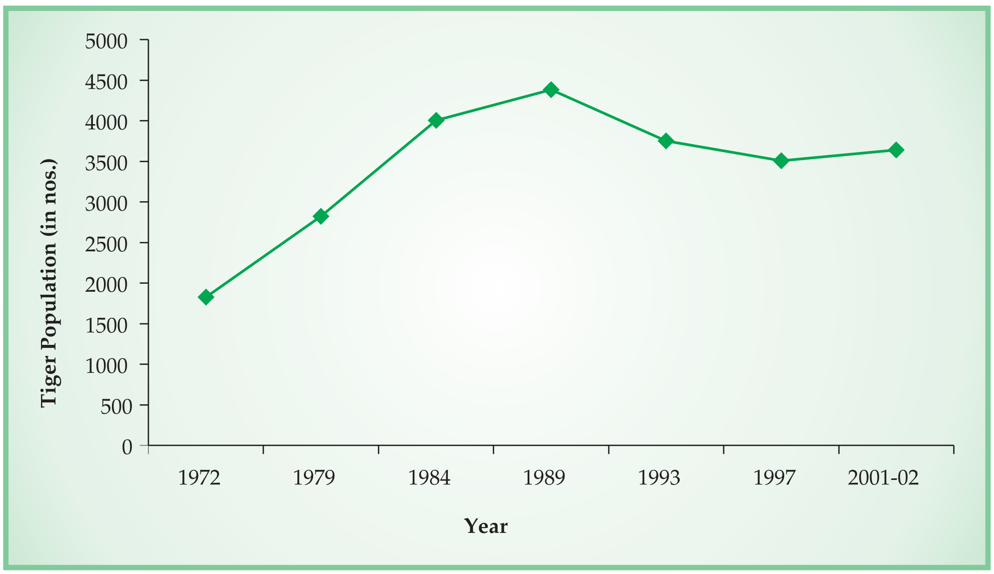
Source: ICFRE Forestry Statistics India (1987, 1996, 2000 and 2001)

6.3.4 Wildlife Management

Wildlife management is part of a comprehensive conservation management strategy of natural resources. The Wildlife Institute of India (WII) was set up in Dehra Dun in 1982 with a mandate to take up research in wildlife conservation and management and to train wildlife managers, researchers, and conservationists. WII's mission is to nurture the development of wildlife sciences and promote their application in a manner that accords with our economic and socio-cultural milieu. It has given a new direction to the concept and practice of wildlife conservation and made it more practical and relevant. Technologies used in wildlife conservation are discussed in this section.

In India, the dwindling population of the tiger has been drawing the attention of the authorities and Project Tiger was launched in 1973. This is a major conservation scheme. Tigers are epitomised as the health of the ecosystems they inhabit and their survival is considered pivotal to the survival of the life support system for other biodiversity components, including humans. Tigers are considered more as representatives of all the biotic components in a given ecosystem rather than an individual species in the animal kingdom. Project Tiger yielded good results in terms of both arresting the declining population of the tiger as well as earmarking vital protected habitat for this magnificent creature.

Figure 6.9: Estimates of Tiger Population in Protected and Non-Protected Areas



Source: ICFRE Forestry Statistics India (2003)

Unfortunately a spurt in tiger-product trade, in particular in South-East Asian countries and China, during 2003 dealt a severe blow to the project. Within a short period more than 200 tigers seem to have been killed for this heinous trade. Recently, the Tiger Task Force (TTF) suggested that scientific methods be used for tiger census and wildlife researchers be involved in the writing of management plans. The Ministry of Environment is processing TTF's suggestion that a special wildlife crime bureau be set up to check poaching.

In India, the population of tigers (in tiger reserves and protected areas) in each landscape complex is being monitored intensively. Tiger abundance and density is estimated biannually, using camera traps, digital images of pugmarks, and / or DNA profiles from non- invasive methods. The pug mark technique for individual tiger identification was developed in 1996 at the Wildlife Institute of India. This is also used for population monitoring of tigers. Based on such technology application the status of tiger population is monitored once in two years in all protected areas and sanctuaries of India. Radio collaring is another technique used in estimating tiger density. In core areas of reserves, tiger densities range from 6 to 8 tigers per hundred sq. km.

Immobilisation of carnivores, elephants and rhinoceros by using drugs is another major technique practised in wildlife management.

Conservation genetics is used for conservation of marine turtles and tigers. India has five of the seven known species of marine turtles and several of these populations are endangered due to exploitation, habitat destruction, and incidental mortality in trawler nets. In recent years the development and integration of molecular techniques in genetic studies have opened up new vistas to seek answers to questions of ecological interest. The information generated by DNA-based molecular tools on the genetics of extinct populations has been found to be immensely useful in designing conservation strategies and framing management policies.

To identify evolutionary significant units of tigers (ESU) that exist within India, tiger scats are obtained from various parts of the country and the conservation genetics laboratory extracts DNA and amplifies specific micro-satellites. A Project Tiger Directorate study has examined whether ESU exists in the country within different isolated tigers conservation units, to assist in prioritising tiger conservation efforts.

Separate software has been developed for use in Global Positioning System (GPS) equipment for various purposes like sighting location of animals, counting, movements, fire detection, survey of land, etc. It could be very effectively used for census and population studies of animals in wild habitats. As a practical application and technology transfer of GPS methodology, a census of giant grizzled squirrels was carried out in March 2006 in the Saptoor forest area of Rajapalayam by the Tamil Nadu State Wildlife Board. The staff was trained in this methodology and a census was conducted on March 13. 201 squirrels were sighted and 370 nests were located in four forest ranges.

Remote sensing and GIS is used for conserving biodiversity in India. In a two-pronged strategy, patterns of distribution of biodiversity at the regional and local scales have been studied to assess the adequacy of protected area coverage in relation to distribution of biodiversity at the regional scales and to develop meaningful correlates and surrogates of biodiversity values which can be used by remote sensing and GIS at local scales. Such a programme was initiated in 1995 with the goal of assessing the adequacy of the protected area network in the Indian Himalayas, to provide coverage to the rich biodiversity, to identify potential areas for conservation, and to develop biodiversity action plans. It relied on use of remote sensing and GIS techniques in combination with field surveys. Satellite Imagery LISS III (digital data) was used in conjunction with Survey of India maps as well as soil and geographical maps. Information on boundaries of area compatible with target biodiversity models was recorded through GPS technology. The maps were digitised and incorporated in GIS domain. A total of 21 districts, 152 tehsils and 167 blocks over 32,450 sq. km have been included in the socio-economic database to produce thematic layers for using and developing an integrated conservation protocol for the western Himalayas.

6.3.5 Forest Protection

Forest protection is an essential component of forestry and covers a diverse field of activities ranging from protection of forests and wildlife from the onslaughts of man, fires, pests and diseases. In detection of forest offences and securing conviction in courts, forensic science plays a salutary role. Modern technology like fire rating systems and availability of instant satellite information has helped to detect fires, thus enabling quick action to control their spreading. The development of Hp NPv technology (Hyblaea puera nuclear polyhedrosis virus) by the Kerala Forest Research Institute (KFRI) has been a major breakthrough in controlling defoliators ravaging teak plantations.[8]

6.3.5.1 Forensic Science in Forest Protection

The aims of the Wildlife Forensic Cell, established in 1995 within WII, are to develop and standardise various techniques for identifying species from varied biological products reported in trade such as hair, bone, claws, teeth, skin and meat. Such identification of species is based on external morphological characteristics, light microscopy, scanning electron microscopy, crystallography, double diffusion, and iso-electric focusing.

One of the important tasks undertaken by the Forensic Cell has been the development of protocols for identifying mongoose species based on hair characteristics (cuticular and medullary patterns), as mongoose hair is widely used in brushes. Of the five mongoose species found in India, protocols have been developed for identifying four species: *Herpestes edwardsi* (common mongoose), *Herpestes smithi* (ruddy mongoose), *Herpestes palustris* (Bengal mongoose) and *Herpestes urva* (crab-eating mongoose). Discriminate Functional Analysis (DFA) using hairband lengths of four apical bands for all four species has been successful in identifying species with 95% accuracy. Medullar characteristics of *H. edwardsi*, *H. smith, H. palustris* and *H. urva* clearly reveal differences among the species. A manual was prepared for identifying 40 different species of Indian wild animals with microphotographs of cuticle, medulla and cross- section of hair. This manual has been updated, improved and replaced with the collaboration of USFWS (United States Fish and Wildlife Service).

Protocols have also been standardised for identifying plucked and shed feathers of peafowl (*Pavo cristatus*) based on root morphology. Work has been initiated for standardising protocols for extracting DNA from highly degraded wildlife forensic materials sent to the Forensic Cell by various enforcement agencies. Different methods (phenol / chloroform, Qaigen, Chelex-100) have been tried and standardised to extract good quality DNA from various forensic samples, such as formalin-preserved meat, hair, musk pod, bear bile, antler, blood, scats, cooked / boiled meat and feathers received in wildlife offence cases. The Cell has also standardised Random Amplified Polymorphic DNA (RAPD) and Polymerase Chain Reaction-Restriction Fragment Length Polymorphism (PCR-RFLP) methods for wildlife parts and products. Morphometric, crystallographic and DNA-based techniques have also been developed to characterise species from bones of major animals such as tigers, leopards, chitals, sambars, etc.

Wildlife forensic knowledge has been disseminated to various law enforcement agencies for implementing the Indian Wildlife (Protection) Act, 1972.

6.3.5.2 Techniques Adopted to Combat Forest Fires

Forest fires are calamitous events that deplete soil, vegetal resources, and animal resources and also indirectly affect the water cycle. Sophisticated satellite / monitoring technology linked with local sites

[8] KFRI has standardised HpNPVtechnology for use in the field and has transferred the technology to the state forest department. A patent has also been applied for the product (Sajeev and Surendrakumar 2006).

provide crucial information which can be continually updated. Satellites fitted with sensors pass over every part of the earth twice daily and therefore have the potential to provide information about forest fires once in every 12 hours. So hotspot maps are prepared every day and distributed to the agencies dealing with forest fires and also to the monitoring agency supporting fire control.

A fire danger rating system has been developed by the Ministry of Environment and Forests in 1990 to help forest managers assess the probability of fires starting in protected areas, the relative rates of their spread, and the intensity with which they will burn.

Mapping forest fires every year provides information about the extent of fires that have occurred in a particular Reserve Forest (RF). District Forest Officers are given this information so that proper planning and management can be undertaken in the forest divisions to minimise the damage due to fires. After having collected forest fire data over a period, it is possible to do modelling in GIS environment and classify the reserved forests into highly vulnerable, moderately vulnerable, and least vulnerable areas.

With the availability of Moderate Resolution Imaging Spectro Radiometer (MODIS) on a daily basis, it has now become possible to do near real time monitoring of forest fires. The Tamil Nadu Forest Department uses different types of satellite data to map fires in the reserved forests of the State. Satellite scenes (IRS ID LIII data of 23.5 M resolution) for the years 2001, 2002 and 2004 pertaining to the fire season in the State, procured from the National Remote Sensing Agency (NRSA), Hyderabad, are interpreted to identify and delineate areas ravaged by fires. Reports giving division-wise, range-wise, beat-wise and forest-wise information on the extent of fires are sent along with maps to the forest divisions for planning and executing preventive measures. Beat and range staff are thus becoming more vigilant.

In addition, the Tamil Nadu Forest Department also receives information about the location of fire occurrence in terms of latitude and longitude within 1-2 days of occurrence from FSI, which downloads the information with the help of the MODIS rapid response system. The location of fires in RF, beat, range and divisions is worked out and the concerned division office is informed

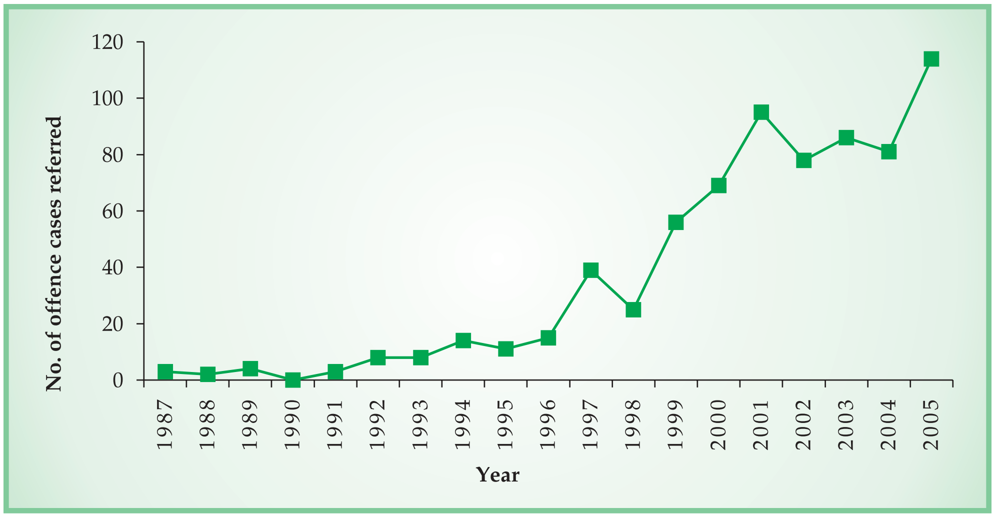
The concept of Integrated Forest Fire Management (IFFM) implemented in the country recognises the traditional role of local people in fire management. IFFM involves planning for the pre-fire stage as well as for fire detection and fire suppression.

Fire occurrence has diminished in protected areas while the situation in the rest of areas remains more or less the same as before. Area involved in forest fires declined from 99,572 ha in 1996–97 to 72,254 ha in 1997–98. Over the same period, the number of forest fire cases reported also declined from 6420 to 2706. However, by 2001–02, area affected by forest fires increased to 1.2 lakh hectares (Forestry Statistics of India, various years).

6.3.5.3 Effect of Forest Protection

One indicator of the effect of various protection measures is the number of wildlife offence cases registered. In the past cases were undetected / unreported and the increasing trend in the number of cases reported indicates the efficiency of protection and control in wildlife management.

Figure 6.10: Detection and Report of Wildlife Offence Cases, 1987-2005



Source: ICFRE Forestry Statistics India (various years)

6.3.6 Forest Utilisation and Research

Ever since its establishment in 1906, the Forest Research Institute has been committed to the evolution and development of scientific forestry in India. Since 1988, the structure, roles and responsibilities of Forest Research Centres spread over the country have been reorganised under the Indian Council of Forestry Research and Education (ICFRE). The main thrust of research activities under ICFRE are in the areas of productivity, efficient utilisation of wood and non-wood products, and development of eco-friendly products and processes.

Cost effective solar kilns for seasoning timber, development of natural dyes from plant materials of forest origin, wood bending through ammonia plasticisation technique are some of the technologies developed by the national research institutes. Innovative process technologies have been developed and diffused by the Indian Plywood Industries Research and Training Institute (IPIRTI) for bamboo and other non-wood products. With the help of various process technologies developed by the Institute of Wood Science and Technology, Bangalore, wood-based panel industries have become technically sound in manufacturing all grades of wood panels to international standards. Areas of technological interventions with regard to wood-based industries are:

1. Total processing technology for plywood manufacture, storage and preservation, veneering, dying, gluing and preservative treatment
2. Adhesive manufacturing technology for all grades of plywood and wood joints processing units
3. Product upgradation, new product development and product standardisation

Some interesting examples of FRI's efforts to save forests are the production of *jigat* and *katha*. Jigat is the powdered bark of the tree, *M.macrantha*. It is used as an adhesive or binder in agarbathi manufacture. With the expansion of the agarbathi industry there has been indiscriminate felling of this tree. FRI has been able to find a substitute, an agro-based biopolymer, for jigat. Laboratory trials with the substitute indicate that the new binder is better than jigat.

Production of katha from the khair (*Acacia catechu*) tree is an important forest-based traditional industry in India. Katha is used in *paan* and in medicinal and ayurvedic preparations. Cutch is a by-product of katha and is used as tanning material and as an additive and preservatives by many industries. In order to restrict the felling of khair trees, FRI has found and developed other suitable sources for making katha. One such source is *Uncaria gambier*.

6.4 Conclusion

The chapter on forestry has discussed the major technological interventions that have been initiated in various spheres of forestry — conservation, restoration, production, protection, wildlife management and utilisation — in India with the objective of managing forests in a sustainable manner.

The impact of satellite technology in forest management has resulted in the appreciation of the status of forest, its deforestation and its condition. The Forest Survey of India's biennial assessment of forest cover has helped in understanding the complexity and challenges facing the country. This challenge has been responsible for the development of an Indian instrument of forest management, namely, the criteria and indicators set out by the Bhopal-India process.

In conservation forestry, data and information generated by the Rapid Biodiversity Assessment has helped in formulating strategies both for *in situ* and *ex situ* conservation which are being adopted and practiced effectively in India. In restoration forestry, significant work in rehabilitation of mangroves is being done all along the Coromandel Coast due to the technology developed and diffused by M.S. Swaminathan Research Foundation. In restoration of forests to original status, Joint Forest Management technology is playing a perceptible role all over the country by enlisting the active participation of people motivated by village forest committees. In production forestry, the large-scale plantation programme as well as clonal forestry and agro forestry have an outstanding record of application diffusion and achievement both in the public and private sectors. In wildlife management, the Wildlife Institute of India has developed relevant grassroot level technology in wildlife management, significant among them being methods to conduct census, radio collaring, use of GPS in conjunction with GIS, and conservation genetics of tiger and turtles. In forest protection, the establishment of the Wildlife Forensic Cell and its role in identification by use of DNA technology, thereby securing conviction for forest offences is a major breakthrough. Several technologies have helped to curtail and control the spread of forest fires.

Carbon sequestration by forests, a function of biomass growth rate is an important and clear indicator that reflects the positive impact of several interventions in the forestry sector. There are several methodologies for estimation of carbon sequestration of forests. The extent of carbon sequestration in Indian forests has been estimated in several studies. The flow of carbon in Indian forests, with reference to the year 1986, has been estimated to be 9.58 million tonnes (Ravindranath et al 1996). Two other studies have estimated the carbon pool or the carbon stock of Indian forests as being 1.28 million tonnes in 1993–94 and 2.0 million tonnes in 1995 (Sekar 1998). It is significant that all three studies have estimated positive flow or stock of carbon sequestration. The status of plantation forests in India provides a possible explanation of such positive flows. In 1980, plantation forests in the country accounted for 3.8 million hectares and this figure has rapidly increased to 18.48 million hectares by 2000. Out of the 18.48 million hectares of plantation forests, at least 10.85 million hectares of the plantations have been in the age group of 10 and above in the year 2001 (Chopra et al 2002). This mix of young and middle-aged plantation forests keep the rate of growth in these tracts much higher than in the natural forests. Thus, even though natural forests may be zero net contributors to the positive carbon flows, the void is more than offset by growing plantations in India.

The Institute of Economic Growth has included tourism and carbon sequestration in its assessment of the contribution of the forestry sector to the country's GDP (Chopra et al 2002). Increasingly, there is recognition of the various services provided by the forestry sector to the development of the nation.

REFERENCES

Chandra, J.P. 2001. "Scope of Poplar Cultivation". *Indian Forester*, January 2001.

Chopra, Kanchan, B.B. Bhattacharya and Pushpam Kumar. 2002. *Contribution of Forestry Sector to Gross Domestic Product (GDP) in India.* New Delhi: Institute of Economic Growth.

Duerr, W.A. 1981. "Productivity as a Forestry Theme", *Journal of Forestry* (Society of American Foresters), August 1981.

FAO. 1996. *Forest Resources Assessment 1990: Survey of tropical forest cover and study of change processes.* Rome.

FAO–FSI, 2004. *Pilot Study on Assessment of Status of Sustainability of Forest Resources in India.* Dehradun: Forest Survey of India.

Forest Survey of India. *State of Forest Reports* 1987, 1989, 1991, 1993, 1995, 1997, 1999, 2001, & 2003. Dehra Dun.

Government of India. 1999. *National Forestry Action Programme – India,* Vols I, II & III. New Delhi: Ministry of Environment and Forests.

________. 2003. *Agriculture Statistics at a Glance.* New Delhi: Department of Agriculture and Cooperation, Ministry of Agriculture.

Government of Tamil Nadu. 2006. *Information HandBook.* Tamilnadu Afforestation Project. Chennai: Tamil Nadu Forest Department.

Indian Council of Forestry Research and Education (ICFRE). *Forestry Statistics India – 1987 to 2004.* Dehra Dun.

_________. 2000. *National Forestry Research Plan*, Vol. 2. Dehra Dun.

Israel Oliver King. 2005. *Sacred Forests of Kolli Hills, Tamil Nadu, India: A study on botany, ecology and community interactions.* Ph.D Thesis. M S Swaminathan Research Foundation, Chennai.

John Joseph, S. 2005. *Paradigm Shift in Forest Management*. Dehra Dun: International Book Publishers.

Kaushik, R.C. 1969. "Changing Patterns of Forest Management in India". *Indian Forester*, August 1969.

Kotwal, P.C., Dharmendra Chandurkar, Yogesh D. Jadhav, Navin Vivek Horo and D.Dugaya. 2002. *Illustrated Manual on Criteria and Indicators for Sustainable Forest management.* Bhopal: Indian Institute of Forest Management.

Kulkarni, H.D. 2002. *Bhadrachalam Clones of Eucalyptus – An achievement of ITC.* Dehra Dun: ICFRE.

Maheswar Rao, G., et al. 2001. *Genetic Improvement of Casurina equisetifolia.* Coimbatore: Institute of Forest Genetics and Tree Breeding.

MANAGE, 1999. *Extension Digest.* Hyderabad

Mathur, R.S. 1976. "Productivity Trends in Indian Forestry". *Indian Forester,* June 1976.

Nayar, M.P. and A.R.K. Sastry (eds). 1987, 1988, 1990. *Red Data Book of Indian Plants,* Vols, 1, 2 and 3. Calcutta: Botanical Survey of India.

Piare Lal and H.D. Kulkarni. 1993. "Improving Land Productivity and Returns from Agro Forestry Plantations". *Indian Forester,* June 1993.

Poyry, Jaakko, 2004. *Forests and Wildlife Statistics-India.* New Delhi: Ministry of Environment and Forests, Government of India.

Ramakrishnan P.S. 1993. "Evaluating Sustainable Development with People's Participation." In Franz Moser (ed). *Proceedings of International Symposium on Sustainability: Where Do We Stand?* Graz, Austria: Technische Universitat.

Ravindranath, N.H., B.S. Somasekar and Mahadev Gargil. 1996. "Carbon Flows in Indian Forests". *Climate Change*: 33 (3).

Sajeev, T.V and V.V. Sudhendra Kumar. 2006. *Hp NPV Technology for Bio-control of Teak Defoliator- Hyblaea puera.* Peechi: Kerala Forest Research Institute.

Sekar, C. 1998. *Extent of Wastelands and Common Property Resources in India.* New Delhi: Institute of Economic Growth.

Selvam, V., V.M.Karunagaran, K.K.Ravichandran and G. Evanjaline Jessies Beulah. Undated. *Joint Mangrove Management in Tamil Nadu*. Chennai: M S Swaminathan Research Foundation.

Singh, K.D. 2005. *Exploring Options for JFM in India*. Rome: FAO.

Sreedharan, C.K. 2002. "An Integrated Approach to Conservation of Forests with Development of Villages in Tamil Nadu". Paper presented at the *International Workshop on Forest Science and Forest Policy in the Asia-Pacific Region: Building Bridges to a Sustainable Future*. IUFRO / MSSRF / USDA.

Van Viet. 1987. "Forestry Poly Science in Development. A Systematic Approach". *Nederlands Bosbouw Tijdschrift* 64(3).

Wildlife Institute of India. *Annual Reports*, 2000-01, 2001-02, 2002-03, 2003-04. Dehra Dun.

http://en.wikipedia.org/wiki/List_of_Biosphere_Reserves_in_India

www.faostat.org

www.itcpspd.com/technology/clonal

7

HEALTH*

7.1 Introduction

The use of science and technology for the improvement of the health of mankind is not a recent development. There are evidences that cavemen used flints to amputate limbs. Medical science was fairly advanced and the diagnosis and treatment of various diseases were carried out in India from time immemorial. Many surgical concepts and instruments are described in the ancient surgical text, *Susruta Samhita*, believed to have been written 3000 years ago by the ayurvedic scholar, Susruta (Park 2005). The development of the concepts of hygiene, antisepsis, anaesthesia and vaccines, and the invention of microscopes and x-rays transformed the practices of medicine in the 19th century and paved the way for a greater impact of science and technology on the medical field. Further, discoveries of causative agents, establishment of the germ theory and modes of transmission of diseases, and development of vaccines, antitoxins and disinfectants also provided a firm foundation for preventive medicine in the later half of the 19th century. The post-war years of the 20th century is said to be one of the best periods in the history of medicine with advances in surgical techniques, significant innovations in drug manufacturing and development of new ideas about the nature of diseases.

Over the years, the scope of medicine has broadened to include prevention of disease, promotion of health and improvement in the quality of life of the people, in addition to the traditional goal of treatment of sickness. Further, various studies in the early 1980s have shown that health outcomes are related not only to advances in medicine but also to improvement in diet, housing, water supply, sanitation and environment. Medical advances combined with social strategies have helped contain major health problems across the world.

7.1.1 The Indian Scenario

The leading health problems of rural communities in India can be classified as communicable diseases, vaccine-preventable diseases, non-communicable diseases and major nutritional deficiencies. Since Independence, several national level health programmes have been initiated in our country, to tackle specific diseases. The objectives of these health programmes have been:

- to control, that is, to bring down the prevalence or incidence rate of specific diseases to a level where they no longer remain a public health problem
- to eradicate the health problem

In this chapter, the attempt is to study the technical as well as managerial aspects of the various health programmes that have been initiated, and analyse their impact. The successful control of the various health problems is a measure of the impact of the programmes implemented. The impact of the health programmes is measured using parameters like prevalence, incidence, morbidity, mortality rates, etc. of diseases. However,

* Contributed by Dr. K. Susheela, a medical professional based in Bangalore.

data on incidence or prevalence of various diseases are not available separately for rural areas and pertain to the country as a whole. Therefore, while it has not been possible to estimate the impact of specific programmes on rural health, given that 70 % of India's population live in rural areas, the estimates for the country may be taken to reflect the rural reality. Nevertheless, using indicators such as Infant Mortality Rate (IMR) and Life Expectancy Rate, an assessment of progress in the overall health status in rural India is provided. **Table 7.1** provides a list of major diseases considered in this study.

Table 7.1: Major Health Problems of Rural India

Category	Diseases
Communicable	Malaria, leprosy, tuberculosis, cholera and diarrhoeal disorders, HIV / AIDS
Vaccine-preventable	Poliomyelitis, diphtheria, pertussis, tetanus, measles, tuberculosis
Non-communicable	Preventable blindness
Major nutritional deficiencies	Vitamin A deficiency disorders, protein energy malnutrition, iron deficiency in children and women of childbearing age, iodine deficiency disorders

The list of diseases discussed here do not include lifestyle diseases or diseases of urban living such as hypertension, diabetes mellitus, cancer, etc., as not much work has been done in this field and therefore neither the exact incidence / prevalence of these diseases nor the success of measures taken to contain them are known. Most of the national health programmes attempt to tackle diseases using simple technologies that are compatible with primary health care.

7.2 Communicable Diseases

7.2.1 Malaria

Malaria is a protozoal disease caused by parasites of the genus *plasmodium* and transmitted to man by the bite of certain species of infected female anopheles mosquitoes. The British army surgeon, Ronald Ross, discovered the malaria parasite in the gut tissue of the female anopheles mosquito way back in 1897 in his laboratory in Secunderabad, India. Among the four types of malaria parasites — *Plasmodium vivax* (PV), *Plasmodium falciparum* (PF), *Plasmodium malaria* (PM) and *Plasmodium ovale* (PO) — three are prevalent in India. Clinical signs and symptoms and definitive intermittent periodicity of the attack of the disease help in the diagnosis of malaria. However, for purposes of treatment, the confirmation of the presence and type of malaria parasite by the microscopic examination of thick and thin blood smears is mandatory. Scientific studies have shown that malaria parasites develop in liver tissues and red blood cells in the human host. A few of them develop into male and female gametocytes inside the red blood cells. To be infective to the mosquitoes, a patient should harbour viable, mature, male and female parasites in a minimum required density, i.e., at least 12 per cc of blood. Of the different types of malaria parasites, the parasite *Plasmodium falciparum* (PF) could cause serious complications in the patients.

The clinical cure of malaria can be achieved by presumptive treatment, by administering a single dose of chloroquine. But to ensure complete cure of the disease, radical treatment with a combination of primaquine and chloroquine is necessary. Research has shown that the insecticide DDT can kill, shorten the life span, and repel adult anopheles mosquitoes, with its residual effect lasting for 10-12 weeks. Subsequent studies have also shown that malathion and synthetic pyrethroid have insecticidal properties against anopheles mosquitoes. Therefore these insecticides were used wherever the vectors developed resistance to DDT. Thus, the presumptive and radical treatment against malaria and preventive measures against the transmission of the disease have been developed.

7. 2.1.1 National Programme on Control /Eradication of Malaria

The National Malaria Control Programme (NMCP) was launched by the Government of India in April 1953, with the main objective of reducing the incidence of malaria. Highly malarial areas, with spleen rate of more than 10, were brought under this programme.[1] The aim was to control malaria by using indoor residual insecticide spray twice a year. With the initiation of this programme, the number of malaria cases came down to 2 million by 1958 from 75 million cases in 1947. Encouraged by the spectacular result of NMCP, coupled with the fear that the insect vector might develop resistance to insecticides, the government launched the National Malaria Eradication Programme (NMEP) in 1958. The objectives of NMEP were to end transmission of malaria, to eliminate the reservoir of infection, and to eradicate the disease within a time frame of 10 years. The attack phase started in 1958 with every house in the malarial tracts of the country being sprayed with an insecticide, twice a year, for a period of 3 to 4 years, during the malarial transmission seasons. By 1959 all malarial tracts were brought under insecticidal spray. Surveillance, that is, a programme of case detection and treatment, was instituted in 1960. Surveillance workers visited each house once every fortnight looking for fever cases. Blood sample smears were collected from affected patients and presumptive treatment was started. Later, if laboratory tests of staining the blood smears by the JSB method[2] confirmed the presence of malaria in any of the cases, radical treatment was administered. By 1961, the annual parasitic index (API) came down to 0.1 from 4.89 in 1958.[3]

The consolidation phase was launched in 1962 and the regular spraying of insecticide was withdrawn. But active and passive surveillance as well as presumptive and radical treatment and epidemiological investigations of cases continued. Remedial measures like focal spray in areas where API was 2 or more were instituted. The maintenance phase, the last stage of NMEP, was started in 1966, when the responsibility of maintaining the 'malaria free' status was transferred from the Government of India to the public health departments of concerned State governments.

However, large-scale outbreaks soon occurred, which could not be liquidated by routine measures and the yearly incidence of the disease began to increase. In 1976, the number of cases reached 6.4 million and API reached an all time high of 10.54. Setbacks in malarial control related to administrative failures like shortage of finances, manpower and insecticides as well as operational failures like lack of sufficient transport, migration of labour and refusal to spray houses on religious grounds. This was aggravated by technical hurdles, like the development of resistance to insecticides by the vector and the emergence of chloroquine-resistant PF species. These setbacks occurred at a time when greater effort was needed to root out the remaining pockets of endemicity in the country. In view of such problems, the government constituted two committees in 1974 to re-examine and recommend a suitable anti-malarial strategy. Based on their recommendations, the Modified Plan of Operation (MPO) was launched in January 1977 (Directorate of NMEP 1976). Though its goal was the eradication of malaria, no time limit was fixed to complete this task. The objectives were to prevent malarial deaths and morbidity. Under MPO, the different phases of NMEP

[1] Spleen rate refers to the percentage of children between the age of 2 and 10 years showing enlargement of the spleen.

[2] Two Indian Scientists Jaswant Singh and Bhattacharya developed a method of staining referred to as JSB staining.

[3] Annual parasitic index (API) is the ratio of microscopically confirmed malaria cases in a year for every 1000 population under surveillance.

were abolished and areas were reclassified on the basis of the annual parasitic index as areas with API 2 or more and areas with API less than 2.

Table 7.2: Malaria in India, 1947-2003

Year	Number of malaria cases reported per year (in million)	Number of PF cases reported per year (in million)	Number of deaths reported due to malaria per year	API
1947	75.00	N A	8,00,000	-
1958	2.00	N A	N A	4.89
1961	0.05	N A	Nil	0.12
1969	0.35	N A	N A	0.68
1976	6.40	0.75	59	10.54
1981	2.70	0.59	170	3.98
1985	1.86	0.61	213	2.52
1996	3.04	1.18	1,010	3.48
2000	2.03	1.50	932	2.09
2003	1.64	0.70	943	1.62

Note: Mid-year population data as given in EPW, 2005 is used in the calculation of API; NA-not available.

Source: 1947and 1976 - Ministry of Health and Family Welfare, Government of India (various years); 1958, 1961, 1969 - Park and Park (1977); 1981 and' 85 - Government of India (1986); 1996, 2000 and 2003 - Ministry of Health and Family Welfare, Government of India (2004).

Areas with API 2 or more were further divided into responsive and non-responsive, depending on the susceptibility of the mosquito vector to DDT. Responsive areas received two rounds of spray with DDT and non-responsive areas received alternative insecticidal sprays. Anti-larval measures were also taken up in these areas. In areas where API was less than 2, regular insecticidal spray was stopped. Focal spray was undertaken wherever PF cases were detected. Under MPO, active and passive surveillance were undertaken vigorously, and presumptive and radical treatment was administered without fail. About 3.57 lakh drug distribution centres and fever treatment depots were opened all over the country where presumptive treatment was administered, and blood smears collected from fever cases. Voluntary workers from the community managed these centres. In October 1977, the PF containment programme was introduced and special inputs were provided to strengthen the field operation. Also in 1977, the WHO expert committee on malaria re-evaluated the anti-malarial measures into measures to be taken by individuals and those by the community. The former measures included prevention of man-vector contact by using mosquito repellents and bed nets, destruction of mosquito larvae by intermittent drying of domestic water containers, filling small scale drainage and stagnant water ponds, and taking chemotherapy. The measures taken by the community comprised destruction of adult mosquitoes by residual spray and that of larvae by either chemical or biological barricades as well as prevention of the spread of malaria by environmental, water and drainage management.

After the commencement of MPO in 1977 the incidence of malaria began to decline, from 6.4 million cases in 1976 it came down to 2.18 million cases in 1984. But once again it started rising in the late 1980s and early 1990s. The government constituted an expert committee to review the situation and to identify the problem areas. On the basis of its recommendations, the Malaria Action Plan was started in 1995. Under this plan, bioenvironmental methods to control mosquito breeding intensified. Information, education and communication initiatives and community mobilisation programmes were started. Drug policies were revised in high-risk as well as other areas. The drug policy was also changed in areas with chloroquine-resistant PF cases. In 1997, an Enhanced Malaria Control Project was launched in 1045 primary health centres. In the last two decades there has not been much change in the incidence of malaria in the country. The consolation is that the incidence has not increased and the percentage of population with malaria per year has come down.[4] **Table 7.2** clearly brings out the reduction in the number of reported cases of malaria since Independence, while PF malaria continues to remain a major problem. According to the Director, National Institute of Malaria Research, PF malaria accounted for around 50 % of the cases in 2005 and is present in all parts of India (Ramachandran 2006).

7.2.2. Leprosy

Leprosy has affected mankind from time immemorial. Leprosy is a chronic infectious disease caused by *Mycobacterium leprae* (*M.leprae*), an acid-fast, rod-shaped bacillus. The disease mainly affects the skin, the peripheral nerves, mucosa of the upper respiratory tract and the eyes. In the year 1873, Hansen of Norway identified *M.leprae* to be the cause of leprosy. The clinical manifestations of this disease are the presence of hypo-pigmented or erythematous patches on the skin with altered or definite loss of touch, pain, heat and cold sensations and the presence of thickened tender cutaneous nerves.

Dapsone, a sulphone drug, was introduced in the treatment of leprosy in 1943. By the 1970s it became obvious that the effort to control leprosy by long, continued, even life-long Dapsone monotherapy was failing and the bacilli were developing resistance to the drug. This led to the establishment of research programmes to develop vaccines to protect the population from the infection and more effective treatment to cure the disease. The similarity between tubercular bacilli and lepra bacilli prompted researchers to try multi-drug therapy to treat leprosy. Hence two or more drugs, each acting by different antimicrobial mechanisms, were used in different regimens for different types of leprosy.

In 1981, the WHO study group on chemotherapy of leprosy reclassified leprosy patients as having multibacillary leprosy (MB) or paucibacillary leprosy (PB), according to the degree of skin smear positivity. A bacterial index for grading such positivity through slit skin tests was evolved by the Indian leprologist, Dharmendra. Known as Dharmendra's scale, this is being used all over the world.

However, in 1993, in view of the fact that facilities for slit skin tests were not available everywhere, another system of leprosy classification based on the number of skin lesions in a patient came into force.

1. Single lesion PB patients
2. PB leprosy patients with skin lesions of 2 to 5
3. MB cases with more than 5 skin lesions

7.2.2.1 National Programmes on Leprosy Control / Eradication

The Government of India's National Leprosy Control Programme was launched in the year 1955. The aim was to detect cases early and treat the patients with Dapsone, the only medicine available at that time. Detection was done by passive surveillance among the patients who attended the hospitals with complaints. Diagnosis of cases was done by clinical methods. Skin smears for bacteriological diagnosis was rarely done. Free treatment was given to patients on an ambulatory basis. In the absence of any clear cut policy and stipulated duration for the treatment, infected cases received the drug life long. The programme was carried out under the leprosy control units in endemic areas.

[4] Percentage of population with malaria per year is estimated using the data on number of cases reported and the population for the corresponding period.

By the 1970s, *M. leprae* started developing resistance to Dapsone. In the absence of an effective alternative medicine, the future of the programme appeared bleak. In 1980, the government formed a committee to evolve a strategy to eradicate leprosy from the country by the end of 2000. A pilot project was undertaken to study the effects of combinations of drugs on different types of leprosy, and a report was submitted to the government in 1982. The report recommended multi-drug therapy (MDT) to eradicate the disease.

In 1983, the National Leprosy Control Programme (NLCP) was re-designated as the National Leprosy Eradication Programme (NLEP) and launched in a phased manner. The aim of the programme was to reduce leprosy cases to 1 / 10,000 population by the end of 2000 through early detection of cases (necessary to prevent deformities) and treatment with MDT. Early detection and cure of the cases were necessary as it helped in preventing the deformities in the patients. Case detection was continued by passive surveillance among patients who attended health institutions. But active surveillance became an important strategy under NLEP where the surveillance workers went on house-to-house visits and detected cases. They collected information about patients and their contacts within and outside the families. Population surveys were also undertaken.

Diagnosis of leprosy was done mainly by simple clinical methods under NLEP. In the early period of NLEP, bacteriological positivity was mandatory for the diagnosis of MB leprosy. But in 1993, to promote early detection of leprosy by trained health and community workers, the clinical method of detection was used as the diagnostic method for all types of leprosy. Under MDT all the medicines used were bactericidal. There were fixed regimens and stipulated durations of treatment for each type of Leprosy. The treatment was free and on an ambulatory basis. The medicines to be consumed once in a month were administered under direct observation. The medicines for daily consumption were collected by the patients once a month, and self-administered.

In India, Rifampicin, Clofazimine and Dapsone were the three drugs used to treat MB leprosy. Rifampicin was to be taken once a month; Clofazimine was used in varied doses on alternate days or daily; and Dapsone for daily use. The treatment was given for one year. For PB leprosy, Rifampicin once a month and daily doses of Dapsone were prescribed. The duration of treatment was for 6 months. Multicentric double blind trials showed that single lesion PB leprosy could be cured by a single dose of 600 mg of Rifampicin 400 mg of Ofloxacin, and 100 mg of Minocycline (WHO 1998). This led to the administration of multi-drug, single-day, single-dose therapy for single lesion PB leprosy.

Rehabilitation was an integral part of the leprosy eradication programme. This was done by well planned medical, surgical, social, educational and vocational actions, to provide the disabled leprosy patients the highest possible level of functional ability. Under NLEP, health education was directed towards the patient and his family as well as general public. A nationwide mass education programme was undertaken to create awareness among people on the true facts about leprosy, and to remove the stigma and superstitions associated to it. Emphasis was laid on the fact that a cured but mutilated patient did not transmit the disease and this helped in removing the fear in the minds of people about the infectious nature of leprosy. Hence treated leprosy patients were accepted by society and treatment on ambulatory basis was also made possible. The education programmes showed that the primary disabilities of leprosy could be prevented by early detection and treatment of cases. Educating the patients in the importance and techniques of self care prevented secondary disabilities.

NLEP was implemented in the endemic rural areas through the establishment of leprosy control units (LCUs) and survey, education and treatment centres. Each LCU, covering a population of 4.5 lakhs, was assigned one medical officer, 2 non-medical supervisors and 20 paramedical workers. Survey, education and treatment centres were attached to the primary health centre and placed under the administrative control of its medical officer. In non-endemic areas, mobile leprosy treatment units (MLTUs), with one medical officer, one non-medical supervisor, two paramedical workers and a driver provided the services. Though the progress under NLEP in reducing the prevalence and incidence rate of the disease in the country was good, the achievement was not uniform in all the States. Therefore, the Modified Leprosy Elimination Campaign (MLEC) was started in 1997. Short-term leprosy orientation training was given to medical officers, health workers and volunteers, who undertook house-to-house searches to detect leprosy cases and create awareness about the disease.

7.2.2.2 Prevalence and New Case Detection of Leprosy in India

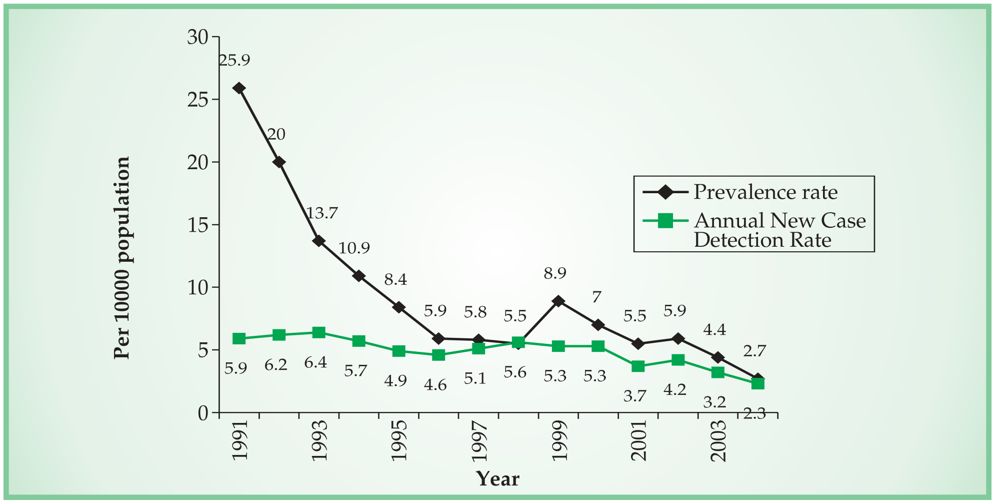
The prevalence rate (number of cases per 10,000 population) and the new case detection rate (number of new cases detected per 10,000 population) with regard to leprosy in the country indicate the effectiveness of the programmes: there is a rapid reduction in the prevalence rate from 57.3 in 1981 to 2.7 in 2004 and with the launch of MLEC, case detection has increased (Park 2005). The status report of the WHO Leprosy Elimination Project, 2003, indicates that Tamil Nadu and Andhra Pradesh, which accounted more than 50 % of the total leprosy cases in the country in 1963, are nearing the goal of 'elimination of the disease' with a prevalence rate of 2.34 and 2.53 respectively in 2002–03. Further, the States of Punjab, Nagaland and Haryana have reached a prevalence rate of less than 1 per 10,000 population. A very high percentage of people of Indian origin are said to have inborn resistance to the disease. A large percentage of PB leprosy in children gets spontaneously cured without any treatment.

Table 7.3 Annual Prevalence and Case Detection of Leprosy in India (in lakhs)

Year	1986	1988	1990	1992	1994	1996	1998
Annual Prevalence	29.16	29.62	26.33	16.73	9.42	5.73	5.32
Annual case detection	4.77	5.19	4.66	5.17	4.94	4.25	5.32

Source: Ministry of Health & Family Welfare (2000).

Figure 7.1: Trend of Leprosy Prevalence and Annual New Case Detection Rates



Source: Park (2005)

7.2.2.3 Anti-Leprosy Activities of Voluntary Organisations in India

Anti-Leprosy work started in India with the founding of The Mission to Lepers (New Leprosy Mission) in 1874. Now there are about 150 voluntary organisations functioning all over India, the major ones being Hind Kusht Nivaran Sangh, Gandhi Memorial Leprosy Foundation at Wardha, the German Leprosy Relief Association, the Damien Foundation and the Danish Save the Children Fund. The National Leprosy Organisation came into being in 1965.

7.2.3 Tuberculosis

In 1882, Robert Koch identified the bacilli, *Mycobacterium tuberculosis*, as responsible for tuberculosis, the chronic infectious disease. Tuberculosis (TB) can attack any part of the body, but pulmonary tuberculosis is the most common manifestation of the disease. Infectious droplets of TB bacilli are discharged in the sputum produced by patients while coughing. Chest x-rays do not generally reveal pulmonary tuberculosis; the microscopic examination of sputum is more objective and reliable. Sputum-positive cases are infectious cases. Tuberculosis in other parts of the body is diagnosed by different methods like x-rays, biopsy, histological and microbiological examination of specimens obtained from the affected site.

7.2.3.1 National Programme on Control of Tuberculosis

The Government of India launched the National Tuberculosis Control Programme (NTCP) in 1962, with the short term objective of detecting the maximum number of sputum positive cases at an early stage in the disease by passive surveillance and the long-term objective of reducing the disease in the community to a level at which it ceases to be a public health problem.

The District Tuberculosis Control Programme (DTP) was the backbone of NTCP, with the district TB centre (DTC) set up as its nucleus to plan, organise and implement the programme. DTP consisted of one DTC and an average of 50 peripheral health institutions. Under the programme, a target to detect 5 sputum-positive cases per month or 60 cases per year through sputum examination was fixed for each primary health centre. The strategy of active surveillance was also applied to improve the number of cases detected. Each male health worker collected the sputum of people having a cough for more than 4 weeks duration in his area, and the sputum was subjected to microscopic examination to detect the presence of tubercle bacilli. These strategies helped in efficient case detection.

Under NTCP, the medicines used were INH, Thiacetozone, P.A.S. and Streptomycin. Free multi-drug therapy, without a fixed drug regimen, was offered on a monthly domiciliary basis, for a full year or more. If a patient failed to collect the medicine on the due date, a reminder was sent to him to collect the drug (first action). If the patient did not respond to the reminder even after a week, a home visit was paid by the health worker to convince the patient to continue the treatment (the second action). Duration of treatment as well as type of treatment for tuberculosis varied with site and severity of disease. Short-course chemotherapy was introduced in 18 districts across the country on an experimental basis. By 1987-1988, this treatment was extended to 26 more districts. BCG was included in the universal immunisation programme. DTCs registered all the sputum-positive cases in the district tuberculosis case register. The chronic nature of the disease, the ability of the tubercle bacilli to remain alive in the body for years, and the relatively high reactivation rates became major obstacles in the rapid control of the disease. Therefore, tuberculosis continued as an important and problematic communicable disease.

To tackle the problem more effectively, the government launched its Revised National Tuberculosis Control Programme (RNTCP) as a pilot project in 1993. In 1997 this was upgraded as the major TB control programme. The main objectives of RNTCP were to treat, cure and reduce mortality and morbidity due to tuberculosis, prevent the relapse of the disease and reduce the transmission of the disease by breaking the chain of transmission.

The components of RNTCP included:

- *Diagnosis by quality microscopy*: Under RNTCP, the collection of sputum by active surveillance was stopped. Three samples of sputum were collected from patients attending the general outpatient departments of hospitals, who complained of a history of cough of more than 3 weeks duration. These samples were subject to microscopic examination after appropriate staining to detect the presence of *Mycobacterium tuberculosis.*
- *Directly observed therapy short course (DOTS)*: A community-based tuberculosis treatment and care strategy, which combined the benefits of supervised treatment and community-based care and support, DOTS ensured high cure rates through appropriate medical treatment, supervision and motivation by health or non-health workers, and monitoring of the status of the disease by the health service. High potency bactericidal drugs like INH and Rifampicin were prescribed. Supervision of treatment was done either by health workers or by agents (voluntary workers such as teachers, ex-patients, social workers or *anganwadi* workers).
- *Adequate supply of short course chemotherapy drugs*: For each patient, drugs for the full course of treatment were maintained separately. Under no circumstances were these drugs used for another patient. This ensured the continuous, adequate supply of free medicine to all patients on a domiciliary basis.
- *Accountability*: Under RNTCP, the provider was accountable for the completion of the treatment of each tuberculosis patient. The interruption of treatment could be easily detected by the treatment card maintained by the provider. In such cases the patient had to be contacted and convinced to complete the treatment.

As in the case of NTCP, RNTCP was also implemented through the District Tuberculosis Programme. There were 390 DTCs in the country by 1999. At the sub district level, there was one TB unit for an approximate population of 5 lakh. Two percent of the total population of India was covered by RNTCP by the end of 1998. During the later half of 1998, large scale expansion of the programme was undertaken. As of mid-1999 about 130 million people were covered in 61 districts. Nearly 15,000 patients were being placed on RNTCP treatment each month.

7.2.3.2. Prevalence of Tuberculosis in India

The only reliable source of information on the magnitude of the TB problem is sample surveys.

Table 7.4: Incidence of Tuberculosis in India

Year	Incidence of Disease
1998	1.75 per 1000 population
1999	1.50 per 1000 population
2002	1.68 per 1000 population

Note: Incidence of a disease refers to the number of new cases in a particular population in a year.
Source: WHO (1999 and 2000)

Table 7.5: Mortality Due to Tuberculosis in India

Year	Mortality Rate
1964	100 per 1 lakh population
1970	80 per 1 lakh population
1993	53 per 1 lakh population
1998	40 per 1 lakh population
2002	37 per 1 lakh population

Source: Barua (1978); Ministry of Health and Family Welfare (various years)

Since the death rate due to tuberculosis is dropping and the disease is showing a decline, epidemiologists are beginning to think that we may have crossed the peak of the epidemic curve and are somewhere at the beginning of the declining limb (Barua 1978). The review of NTCP by the Government of India with the WHO and the World Bank in 1992 revealed that death caused by TB was at the rate of 1 person / 1 minute. The death rate among the treated sputum-positive cases was 29 % before implementation of RNTCP and 4 % after implementation. By the end of 2001, RNTCP covered more than 40 % of India's population. With the large-scale implementation of RNTCP since 1998, a number of small laboratories have been upgraded for smear microscopy and 2 lakh health workers have been trained in different aspects of RNTCP.

Table 7.6: RNTCP from January 1993 to June 2000

Type of TB	No. of	Treatment Outcome					
	Patients	Cured	Completed	Failed	Defaulted	Transferred	Died
New sputum +ve pulmonary TB	1,22,079	98,302	2,162	3,630	10,928	1,391	5,320
New sputum -ve pulmonary TB	1,00,200	-	84,204	1,356	9,733	929	3,472
New extra pulmonary TB	37,286	-	33,479	96	2,418	310	660
Total new TB cases	2,59,565	98,302	1,19,845	5,082	23,079	2,630	6,452
Relapsed cases	17,557	12,121	577	1,017	2,299	320	1,178
Others	37,410	18,706	7,071	1,932	6,503	569	2,500
Total cases = (new+ relapsed +others)	**3,14,532**	**1,29,128**	**1,27,493**	**8,031**	**31,881**	**3,519**	**13,130**

Note: Data in the above table pertain only to RNTCP and therefore do not include all tuberculosis cases.
Source: www.cde.govt / mmwr / preview / mmwrhtml / mm511102.htm-23k.

India has done pioneering work in controlling tuberculosis. Domiciliary treatment for TB gained worldwide importance, after a study done at the Tuberculosis Chemotherapy Centre, Madras, showed that there was no difference between the numbers of active cases developed among the contacts of patients treated in the hospital and at home (Park 2005). Domiciliary treatment is convenient to the patient and cost effective.

7.2.4. Cholera and Diarrhoeal Disorders

Cholera, an acute diarrhoeal disorder is caused by *V. cholerae* 01, has been present in India since antiquity. Diarrhoea is defined as the passage of stools, more than 3 times a day, with change in character and consistency. Acute diarrhoea starts with sudden onset, and usually lasts for 3 to 7 days or may last up to two weeks. If diarrhoea lasts for 3 weeks or more it is called chronic diarrhoea. Acute diarrhoea is an important cause of morbidity and mortality.

Diarrhoeal diseases have been a major health problem in the country, especially among children under the age of 5 years. In the early 1990s, up to one-third of the admissions into the paediatrics wards of health institutions in the country were due to diarrhoeal diseases and about 17 % of deaths were diarrhoea related (Ministry of Health and Family Welfare, Government of India 1994). Household surveys carried out during 1994 showed that the morbidity rate in terms of diarrhoeal episodes / year / child, under the age of 5 years was about 1.7. According to the WHO estimates for the year 1998, there were about 7.1 lakh deaths and 22 million Disability Adjusted Life Years (DALY) lost due to diarrhoea (WHO 1999).

Studies have shown that 70-80 % of diarrhoeal attacks in India are infectious in origin. Apart from *V.cholera*, rotavirus, *Escherichia coli, salmonella, campylobacter, shigellae, entamoeba* and *giardia* are other microorganisms which cause diarrhoea.

7.2.4.1 National Programme on Control / Eradication of Cholera

The government launched the National Cholera Control Programme during the Fifth Five Year Plan period, aimed at the gradual elimination of cholera from areas where it was endemic. This was to be achieved by carrying out anticipatory preventive measures and surveillance activities for early detection and containment of infection in the endemic states. The programme had various components such as:

- *Early detection of cases and verification of diagnosis*: Cholera can be suspected by means of clinical signs and symptoms during an outbreak of diarrhoea. But confirmation of the disease requires detection and isolation of *V.cholera* 01 bacilli in the stool. Once confirmation of the disease is done, there is no need for examination of stools of all other cases of diarrhoea, in an outbreak.

- *Notification*: Cholera is a notifiable disease locally, nationally and internationally. Within 24 hrs of its occurrence the national government should report it to the World Health Organisation. Reporting of cholera cases and deaths due to it should be continued on a daily and weekly basis, till the area is declared free of cholera. An area is declared free of cholera if no new case has been reported for double the incubation period of the disease after the death or recovery of the last case.

- *Establishment of treatment centres*: In order to control outbreaks of cholera, if no health facility was available in the area, district mobile teams were given the responsibilities of the management of the disease. Any available building could be converted as a treatment centre.

- *Epidemiological investigations*: Epidemiological investigations were undertaken to define the extent of outbreak and to identify the modes of transmission. These investigations helped appropriate measures to be taken to control the epidemic.

- *Sanitation measures*: Contamination of water through the faeces of an infected person is the most common means of transmission of the disease. Contamination of food is often responsible for intra-familial spread. Inadequate sewage disposal as well as inadequate supply of potable drinking water to a community in an endemic area increases its susceptibility to the disease. People were educated in the proper use of latrines and on proper disposal of excreta. Family members of patients were taught methods of disinfecting stools, vomitus, clothes and other personal items of the patients as also latrines (if any) and the house and its surroundings.

- *Vaccination*: Mass scale immunisation was carried out in the cholera-affected areas. As it was difficult to carryout the vaccination in 2 doses, a single dose of vaccination, using double the amount of vaccine, was undertaken.

- *Health education*: Educating people about the benefits of early reporting of diarrhoeal outbreaks, food hygiene practices, washing hands with soap and water after defecation and before eating, consuming cooked food and safe water, using sanitary latrines and not contaminating the soil and water with excreta, all this played an important role both in the prevention and control of cholera outbreaks.

For the treatment of cholera, medicines and intravenous fluids (IV fluids) were used. Medicines such as Tetracylines, Sulphas, Furazolidines and Chloramphenicol were given to eliminate the cholera bacilli from the patient's body. IV fluids such as 'normal saline' and 'ringer lactate' solution were used to replace the water and electrolyte loss. The amount of fluid was calculated in proportion to the severity of the dehydration. It was this fluid replacement which saved the lives of numerous cholera patients.

7.2.4.2 Oral Rehydration Therapy

The government started the National Diarrhoeal Disease Control Programme in 1978 with the objective of reducing mortality and morbidity due to diarrhoeal diseases. In 1980–1981, the National Cholera Control Programme was incorporated in this programme. The National Oral Rehydration Therapy Programme was started in 1986–1987 in a phased manner under the National Diarrhoeal Disease Control Programme.

The introduction of Oral Rehydration Therapy (ORT) in the treatment of acute diarrhoeal disease, including cholera, has been a revolution in the management of these cases. ORT, which has saved the lives of cholera and acute diarrhoeal disease patients the world over, was initiated by health workers in Kolkata (Park 2005).

Oral rehydration therapy was based on the observation that glucose given orally enhances the intestinal absorption of salt and water. Oral rehydration solution (ORS) packets with glucose and appropriate electrolyses were dissolved in drinking water. If ORS was not available, a simple home-made mixture, consisting of 5gm of table salt (1 teaspoonful) and 20gm of sugar (4-5 teaspoonsful), dissolved in 1 litre of drinking water could be used. The amount of ORS prescribed was calculated depending on the severity of dehydration and body weight of the patient.

ORS packets were supplied to needy patients through peripheral health workers and community health workers. Training programmes and health education materials used for educating the public highlighted the rational management of diarrhoea, especially in children, with increased intake of fluids available at home and breast milk. In 1992–1993, the ORT programme became part of the Child Survival and Safe Motherhood programme (CSSM). Two important areas of the programme have been the adequate nutritional care of the child having diarrhoea and the proper advice to the mother on feeding the child. During the episodes of diarrhoea, normal food intake was promoted as soon as the child, whatever its age, was able to eat. Newborn infants with diarrhoea and without signs of dehydration were treated with breastmilk alone. Those with moderate to severe dehydration were given ORS along with breast-feeding.

Low birth weight babies and children with malnutrition are more prone to both infective and non-infective diarrhoeal disorders. Studies showed that improvement in prenatal nutrition would in turn improve the birth weight of the babies as well as the quality and quantity of breast milk. Promotion of breastfeeding would help the infant recover from an attack of diarrhoea, as protective antibodies and nutrients which prevented further infection are available in breast milk. Breast milk also had rehydration effect. It was noted that poor weaning practices were the most common causes of diarrhoea among children between 6 to 11 months of age. Weaning the child not later than the 6th month of life with hygienically prepared nutritious and locally available food reduced diarrhoea.

7.2.4.3 Incidence of Cholera

In spite of the sharp decline in the incidence of cholera as well as percentage of deaths due to cholera during the last four decades, it still remains a threat to public health.

Table 7.7: Incidence of Morbidity and Mortality due to Cholera in India

Year	Cases	Deaths	Percentage of death
1960	14,167	5,220	37.05
1965	43,285	12,947	29.90
1970	17,268	3,801	22.00
1975	21,955	2,320	10.50
1978	10,708	263	2.46
1980	8,717	309	3.54
1985	5,808	155	2.60
1995	3,315	5	0.15
2000	3,807	18	0.46
2001	4,081	6	0.15
2003	2,893	2	0.07

Source: Ministry of Health and Family Welfare, Government of India (1983); Government of India (1994); WHO (1999); Park (2005)

7.2.5 HIV/AIDS

Acquired Immuno Deficiency Syndrome (AIDS) is a fatal illness caused by a retrovirus known as the Human-Immuno-Deficiency Virus (HIV). This virus breaks down the body's immune system, leaving the victim vulnerable to a host of life-threatening opportunistic infections, neurological disorders or unusual malignancies. Once infected with HIV, it is probable that the person will remain infected and infectious to others, lifelong. The term AIDS refers only to the last stage of HIV infection. An HIV-infected person may take 7 to 10 years to develop AIDS.

Treatment with different type of medicines could prevent the multiplication of virus and halt the progression of the disease. The medicines commonly used include nucleoside analogues, for example, Zudovudine (AZT), Didonosine, Staavudine, Hamivudine, and protease inhibitors. In the absence of cure, the treatment is for the duration of the patient's life. In the absence of any effective vaccine to prevent the transmission of HIV, and effective medicine to cure the infection, the only way to check the spread of HIV is the ABC prevention approach: A for Abstinence, B for Being Faithful to Partner and C for Correct and Consistent Condom Use.

7.2.5.1 HIV/AIDS in India and the National Programmes

In India the first case of HIV infection was diagnosed in Chennai, in 1986. In 1990 HIV prevalence reached 5 % among the commercial sex workers and patients attending the STD (sexually transmitted disease) clinics in Maharashtra and intravenous drug users of Manipur. By 1994 the prevalence of HIV reached 5 % among the population at risk in Gujarat and Tamil Nadu. At the same time in Maharashtra the infection started spreading from high-risk groups to the general population and from urban to rural areas. By the year 2000, reported AIDS cases were 8491, estimated numbers of HIV infected were 35 lakh and the HIV infection rate was 418 per 1 lakh population in India (WHO 2000 and KSAPS 2001). The cumulative number of AIDS cases in the country was 86,028 by August 2004 (Park 2005). Analysing the age distribution of AIDS patients, more than 87 % are in the age group 15 to 49 years.

Alarmed by the inroads HIV / AIDS was making in the world, the Government of India constituted a Task Force in 1985 to look into the matter and organise a pilot screening programme of the population at high risk. In 1987, with the first case in the country having already been diagnosed, the National AIDS Control Programme was launched. In 1992, the National AIDS Control Organisation (NACO) was set up to implement and closely monitor the various components of the National AIDS Control Programme. In the same year, the government launched the first phase of HIV / AIDS control project with the following objectives: to prevent further spread of HIV; to reduce mortality and morbidity related to it; and to minimise its socio-economic impact on society. To create awareness among the population about HIV / AIDS, its spread and prevention, the Information, Education and Communication (IEC) activities were started. The second phase of the National AIDS Control Programme was launched in 1999 with international assistance. The objective of the second phase of the programme was to restrict the future spread of the infection to less than 5 % in Maharashtra, less than 3 % in Andhra Pradesh, Karnataka, Tamil Nadu and Manipur, and less than 1 % in the rest of the country (NACO 2000). The programme is implemented both at district and State levels.

Family health awareness campaigns and school health programmes encourage people, not just adults but adolescents too, to approach public health systems for treating reproductive tract infections and sexually transmitted diseases. STD clinics are set up in each District Hospital. Patients from all the peripheral institutions with STD problems are referred here. Free drugs are supplied for the management of STD patients and HIV- positive patients. Steps are being taken to prevent HIV infection through blood transfusion, with a blood bank established in each district hospital and mandatory testing of each bottle of donated blood.

Table 7.8: Managerial Interventions for HIV/AIDS in India

Year	Strategic interventions
1987	National Aids Control Programme
1992	National Aids Control Organisation
1999	National Aids Control Programme - II Phase

7.3 Vaccine-Preventable Diseases

Immuno-biological substances designed to produce specific protection against a given disease are called vaccines. Vaccine-preventable diseases are those diseases whose transmission to susceptible hosts can be prevented by administering specific vaccines.

7.3.1 Small Pox

Small pox is an acute infectious disease, spread mainly by air-borne droplets, and caused by the variola virus. The disease results in a high rate of mortality and morbidity among the affected population. One of the greatest achievements in the history of 20th century medicine, especially preventive medicine, is the eradication of small pox from India (and from the world). As late as 1967, it was endemic in no less than 33 countries (WHO 1977 and WHO 1980). In the eradication of small pox, mass vaccination of the population played a major role. The discovery in 1796 of the highly potent and heat stable vaccine has been one of the greatest discoveries of all times.

Usually the diagnosis of small pox has been done by the combination of clinical methods and epidemiological investigations. Even non-medical persons can diagnose small pox as characteristic rashes appear over the exposed areas of the body. Laboratory testing of specimens collected in a specialised 'specimen kit' from the rashes developed on the body of the patient are either precipitated in gel or cultured on chorioallontoin membrane to arrive at the diagnosis.

7.3.1.1 National Small Pox Eradication Programme

The Government of India launched the National Small Pox Eradication Programme in 1962, with the aim of eliminating the disease form the country. The strategy was to vaccinate all newborn babies and re-vaccinate at least 80 % of the population. Subsequently in 1965, the coverage for re-vaccination was raised to 100 %. As this was not found to be feasible, the government introduced a new strategy based on 'surveillance followed by quick containment'. In 1973, an intensive campaign against small pox was started, with the support of WHO.

In the early stages of the campaign, health workers carried out a monthly house-to-house search to detect cases. Once the outbreak of new cases came to nil, the frequency of search was reduced to once in 2 to 3 months. In 1976, three all India searches were carried out. Health workers visited each house in the areas allotted to them, once in a week or 10 days. Each health worker used a small pox recognition card to detect the cases in the family or in its neighbourhood, and to create awareness among the people. Monetary awards were given to health workers and the public for detecting and reporting cases. The medical officer of the concerned primary health centre visited the area of outbreak of small pox or chicken pox and also areas where there were rumours of outbreak. Weekly surveillance reports were forwarded to higher authorities.

Containment activities were initiated whenever there was a reported or suspected small pox case or an outbreak or whenever there were 2 or more deaths due to fever and skin eruptions without proper diagnosis. Containment activities involved confirmation of diagnosis, detection of other cases, notification of detected cases, and collection of specimen from the diagnosed cases for laboratory confirmation of the disease as well as the application of containment vaccination to household contacts, persons living in the surrounding 50 houses, and people living within a one-mile radius. Vaccination of all previously missed residents, the few temporary absentees, visitors and new comers to the locality, was carried out as and when required.

An outbreak was considered active for 6 weeks and all the containment activities were carried out till that time. The detected cases were isolated in their own houses and disinfection of rooms and articles was done; visitors were restricted from entering the house and strict vigilance was kept to trace the movement of the contacts, within and outside the locality. A containment team comprising supervisors, vaccinators and motivators stayed in the affected area for 3 weeks after the appearance of rashes of the last case detected and till the containment activities were completed. The last indigenous case of small pox occurred in India in May 1975 in Bihar. In July 1975 India was proclaimed to be 'no longer a small pox endemic country'. After a compulsory 2-year period of high quality surveillance and with the absence of any detection of indigenous cases during that period, India was declared a small pox free country in April 1977, by an international commission for the assessment of small pox eradication (WHO 1980).

7.3.1.2 Incidence of Small Pox in India

As a result of the intensive surveillance and quick containment campaign introduced by the government in 1973, the maximum number of cases reported was during 1973 and 1974. The containment and eradication phase of the strategy led to the reported number of cases dramatically declining in 1975 and reaching nil by 1976.

Table 7.9: Incidence of Small Pox in India

Year	Number of cases
1967	84,902
1968	35,179
1969	19,139
1970	12,750
1971	16,184
1972	27,407
1973	88,114
1974	1,88,003
1975	1,436
1976	Nil

Source: WHO (1972 and 1976)

7.3.2 Other Vaccine-Preventable Diseases

Experience with the small pox eradication programme showed the world that immunisation was the most powerful and cost effective weapon against vaccine- preventable diseases. In 1974, WHO notified 6 most common, vaccine-preventable, childhood diseases: viral diseases such as poliomyelitis and measles and bacterial diseases such as diphtheria, pertussis (whooping cough), tetanus and tuberculosis. Vaccines may be prepared from live attenuated organisms (as for BCG, oral polio and measles), or killed organisms (as for pertussis) or detoxicated toxins such as diphtheria and tetanus toxoids. If more than one immunising agent is included in the vaccine, it is called a combined vaccine.

Polio is primarily the infection of the human alimentary tract. The polio vaccine was developed in 1957. This is an oral vaccine that contains live attenuated poliovirus. When administered orally, the virus infects the lining cells of the intestine, multiplies and spreads to other parts of the body and stimulates the body to produce antibodies. This virus, as it is attenuated, loses its capacity to produce disease in the host. The antibodies produced prevent the subsequent infection of the alimentary tract with wild strains of poliovirus. The vaccine progeny is excreted in the faeces. Given the poor sanitary condition in the country, chances of water, food, etc., being contaminated is high, resulting in the spread of live attenuated poliovirus to susceptible contacts. Thus non- inmmunised persons may also be immunized, leading to herd immunity. Further, the polio vaccine is easy to administer and is inexpensive.

The diphtheria and tetanus toxoids are normally used in combination with the pertussis vaccine. Hence it is called the triple vaccine or DPT. It was found that the pertussis component in DPT would enhance the potency of the diphtheria toxoid. In the case of diphtheria and tetanus, antibodies in the mother give natural protection to the new born for a few months. But this is not true with regard to pertussis, even new borns may get the infection. The triple DPT vaccine is given to infants at the age of 6 weeks. In the second booster-immunising dose at the age of 5-6 years, only DT is administered.

Tetanus toxoid administered to antenatal mothers could save them from tetanus related to childbirth and the infants born to them from neonatal tetanus. This led to the administration of tetanus toxoid to antenatal mothers.

Under the Indian vaccination programme, the measles vaccination is given between 9-12 months of age. But whenever there is a measles outbreak in the community the vaccination can be done earlier and a second dose can be given after an interval of 4 weeks.

BCG, the widely used live bacterial vaccine used to prevent tuberculosis was discovered by French scientists Colmette and Guerin. The vaccine was administered by the intradermal technique for the first time in 1927. The strain of bacilli in the vaccine is avirulent to man but retains its capacity to induce an immune response.

7.3.2.1 Strategies Adopted to Tackle Vaccine-preventable Diseases

The government launched its Expanded Programme of Immunisation (EPI) in 1978 with the objective of reducing the mortality and morbidity resulting from vaccine-preventable diseases in children as well as to achieve self-sufficiency in the production of vaccines. EPI meant adding more disease-controlling antigens to vaccination schedules, extending coverage to all corners of the country and spreading services to reach the less privileged sectors of the society.

The Universal Immunisation Programme (UIP) launched in 1985 aimed at total immunisation of children in their first year of life against all the EPI target diseases in the country and immunisation of pregnant women against tetanus. A cold chain system was established for the transportation of vaccines, from manufacturing site to the utilisation site and for the storage at the latter site. Although the target could not be achieved by the planned date of 1990, 'universal immunisation' was interpreted as no child being denied immunisation against these communicable diseases.

Table 7.10: National Immunisation Schedule as per Revised UIP

Category/Interval	Vaccination
For infants	
At birth (for institutional deliveries)	BCG and OPV
At 6 weeks	BCG (if not given at birth) DPT and OPV - I dose
At 10 weeks	DPT and OPV - II dose
At 14 weeks	DPT and OPV - III dose
At 9 months	Measles
For children	
16-24 months	DPT and OPV booster dose
5-6 years	DT Booster (If there is no history or documented evidence of previous immunisation as per UIP schedule, total 2 doses of DT should be given with the interval of 4-8 weeks)
At 10 years	Tetanus toxoid-Booster (If no previous immunisation as per schedule another dose of TT at an interval of 4-8 weeks should be given)
At 16 years	Tetanus toxoid-Booster
For pregnant ladies	
Early in pregnancy	I dose of Tetanus toxoid
4-8 weeks later	II dose of Tetanus toxoid

Note: Interval between 2 doses of same vaccination should not be less than 4 weeks.

Source: Government of India (1994)

A technology mission on vaccination and immunisation of the vulnerable population, especially children, was set up to cover all aspects of the immunisation activity from research and development to actual delivery of services to the target population (Government of India, 1987).

Immunisation services were provided through the existing health care system, such as Maternity and Child Health centres, primary health centres and sub-centres, dispensaries and ICDS units. UIP became a part of the Child Survival and Safe Motherhood programme in 1992 and the Reproductive and Child Health Programme in 1997.

Table 7.11: Decline in Incidence of Vaccine-Preventable Diseases, 1987 to 1999

Diseases	1987	2001	Percentage of decline (1987 to 2001)
Poliomyelitis	28,257	268	99.05
Diphtheria	12,952	4,954	61.75
Pertussis	1,63,786	28,900	82.36
Neonatal Tetanus	11,849	1,354	88.57
Measles	2,47,519	45,301	81.70

Source: Ministry of Health and Family Welfare (2003)

All the vaccine-preventable diseases have been endemic in India, but reporting of these diseases have usually been inadequate. The first reported epidemic of poliomyelitis occurred in and around Bombay city in 1949. The prevalence of polio-lameness among school children in south India was about 3.5/1000 population, annual incidence in the whole population was around 15/1 lakh (WHO 1981). Lameness survey in several north Indian states showed an annual incidence rate of 2 to 5/1000 rural preschool children and 1-3/1000 urban preschool children (Basu 1981). Widespread poliomyelitis epidemics have occurred in 1981 and 1987. The average annual incidence of tetanus was estimated to be 100/1 lakh population (WHO 1978). An estimated 3.5 lakh children died of neonatal tetanus annually prior to the National Immunisation Programme (Government of India 1994).

In the reduction of the infant mortality rate, the implementation of immunisation programmes has played a significant role.

7.4 Non-Communicable Diseases

7.4.1 Blindness

In 1972 WHO defined blindness as, "visual acuity of less than 3/60 (Snellens) or its equivalent". The 19th-century Dutch ophthalmologist Hermann Snellens devised a chart in which the alphabets printed in block letters decrease in size line-by-line to test visual sharpness at various distances. Visual acuity or sharpness of 3/60 can also be measured by the inability to count fingers in daylight at a distance of 3 metres.

The problem of blindness in rural India is acute. Ignorance, poverty, low standard of personal and community hygiene and inadequate health care services, not to mention meddlesome ophthalmology by quacks, all make people more prone to blindness. Quite a good number of the blind in India lose their eyesight before the age of 20 years; many among them are less than 5 years of age. In 1992, cataract was responsible for 81% of total blindness in India while it came down to 62.6 % in 2001–02 (Government of India 1992, and Ministry of Health and Family Welfare, Government of India 2004). Apart from cataract, trachoma, vitamin A deficiency, eye injuries, corneal opacity, refractory error, glaucoma and other causes are responsible for blindness.

Table 7.12: Causes of Blindness in India, 2001-02

Causes of Blindness	Percentage
Cataract	62.60
Refractive error	19.70
Glaucoma	5.80
Posterior segment pathology	4.70
Corneal opacity	0.90
Other causes	6.20

Source: Ministry of Health and Family Welfare (2004)

7.4.1.1 National Programmes to Control Blindness

In 1963, the Government of India launched the Trachoma Control Programme, and in 1976 merged it with the National Programme for Control of Blindness (NPCB), which aimed to reduce the prevalence of blindness in the country to 0.3% by 2000. The programme had two components: an initial assessment of the magnitude and geographical distribution of blindness in the country, followed by methods of intervention such as primary and secondary eye care. The majority of eye conditions were treated or prevented at the grass root level by locally trained health workers. Complicated cases were referred to primary health centres. Under the secondary eye care segment, cataract, glaucoma and ocular trauma were managed by establishing eye departments and clinics across district hospitals and primary health centres. Required ophthalmic manpower was recruited and ophthalmic services and eye camps were started. Cataract surgeries were made available through these camps to the rural masses. General health surveys for the early detection of visual field defects, and information, education and communication activities were undertaken in these camps. The strategies of the programme included the strengthening of service deliveries to provide high quality control treatment. Hence, the physical, technical and managerial capacities of district hospitals, community health centres, and selected non-profit institutions were improved. The promotion of outreach activities, public awareness and development of institutional capacity to expand the accessibility of eye services in rural areas were done on a priority basis.

During 1994–1995, the World Bank-assisted Blindness Control Project was started for a period of 7 years. The objectives of this project were to upgrade the ophthalmic service, to expand the service to rural and tribal areas, to train health personnel, to improve the information system and to create awareness about the programme among the masses by education. Voluntary organisations were encouraged to conduct eye camps in rural areas. The concept of the District Blindness Control Society (DBCS) was evolved under this project and started in five pilot districts to begin with and later expanded to all parts of the country.

A national institute of ophthalmology, the Dr. Rajendra Prasad Centre for Ophthalmologic Science, was established in the All India Institute of Medical Sciences, New Delhi. Ten other institutes of ophthalmology for manpower development, research and referral services were started across the country. During 1981–82, 5.5 lakh cataract operations — both intraocular lens replacement (IOL) and non-IOL surgery — were performed and this figure doubled by 1984–85 with 11.34 lakh cataract operations. From 1985 to 1991, there was a plateau in the performance with 11-12 lakh operations done per annum. From 1991 onwards there has been a rise in the number of operations.

Table 7.13: Number of Cataract Operations, 1992 to 2004

Year	Target (in lakh)	Achievement (in lakh)	Percentage of achievement
1992-93	20.00	16.04	80
1993-94	24.30	19.13	79
1994-95	24.50	21.65	88
1995-96	25.50	24.70	97
1996-97	26.94	27.20	101
1997-98	30.17	30.33	101
1998-99	33.20	33.20	100
1999-00	35.00	35.00	100
2000-01	36.90	36.26	98
2001-02	40.00	37.26	93
2002-03	40.00	38.57	96
2003-04	40.00	41.98	105

Source: Ministry of Health and Family Welfare (Annual Reports various years)

7.5 Nutritional-deficiency Disorders

Nutrition may be defined as the science of food and its relationship to health. The subject of nutrition is very extensive and nutritional deficiency disorders are too many. In this study, vitamin A deficiency, protein energy malnutrition among children, iron and folic acid deficiency, anaemia, and iodine deficiency disorders are discussed.

7.5.1 Vitamin A Deficiency

Deficiency of vitamin A, a fat-soluble vitamin, is one of the causes of blindness. It can also lead to other problems such as xerophthalmia or dry eye which comprises night blindness, conjunctival xerosis (dryness of conjunctiva), Bitot's spot (white powdery spots over the conjunctiva), corneal xerosis (dryness of cornea) and keratomalacia (opacity of the cornea). The extra-ocular manifestations of Vitamin A deficiency are hyperkeratosis (a skin problem), anorexia (loss of appetite) and growth retardation**.**

Vitamin A deficiency has been a major health problem in our country, especially in rural areas, and among children aged 6 months to 6 years. A nation-wide survey between 1971 and 1974 showed that vitamin A deficiency accounted for 0.3 % of the total blindness in India (Park 2000), and a large number of children suffer from sub-clinical deficiency. The government started its national vitamin A prophylaxis programme in 1970, initially in a few districts where vitamin A deficiency was severe, and the coverage has increased gradually. In the short term, 5 doses of vitamin A supplement — first dose of 100,000 units and subsequent doses of 200,000 units — were given to all the children under the age of 3 years. The long term measures included educating the people in general and mothers in particular about the importance of promoting breastfeeding as long as possible as well as consuming food rich in vitamin A like fish liver oil, eggs, butter, cheese, whole milk and meat, green leafy vegetables, etc. In 1992, the vitamin A prophylaxis programme was integrated into the Child Survival and Safe Motherhood programme. The share of vitamin A deficiency in the total blindness statistics came down to 0.04 percent during 1986-89 from 0.3 percent in the early 1970s (Park 2005).

7.5.2 Protein Energy Malnutrition (PEM)

Inadequate intake of food, both in quality and quantity, could lead to protein energy malnutrition. Failure of lactation, short duration of breastfeeding, faulty child- weaning and rearing could also cause protein energy malnutrition. Diarrhoea, respiratory infections, measles and worm infestations increase the requirements of calories, protein and other nutrients in the body, but at the same time reduce their absorption. To a certain extent, a child's nutrition status depends on the health and nutrition status of his / her mother. Improvement in the nutrition of pre- and post-natal mothers results in improvement in the birth weight of newborns as well as in better quality and quantity of breast milk. These factors, in turn, could prevent infections in infants and children.

Diagnosis of protein energy malnutrition is by comparing the weight, height and / or mid- arm circumference of a child with anthropometric norms for the corresponding age in the community. When a child's age is known, measurement of the weight enabled almost instant monitoring of the growth. The measurement of height assessed the effect of nutritional status on a long-term basis.

Protein energy malnutrition has been identified as a major nutritional problem in our country, especially in rural areas. It occurs frequently in children in the early years of life. It is not only an important cause of childhood mortality and morbidity, but also leads to permanent impairment of physical and possibly even mental growth of those who survive. Nutritional marasmus (a form of severe protein-energy malnutrition characterised by calorie deficiency and energy deficiency) is more common than kwashiorkor (a type of childhood malnutrition caused by inadequate protein intake in the presence of fairly good total calorie intake) in India.

Large scale feeding programmes set up by the government include:

1. The Special Nutrition Programme, started in 1970 by the Ministry of Social Welfare for the nutrition benefit of children below 6 years of age and pre- and post-natal women in tribal and backward rural areas, provided food supplements for 300 days in a year. Each beneficiary child received food equivalent to 300 kcal and 10-12 g of protein / day, and the mother received 500 kcal and 25 g protein / day. The programme was later merged with the ICDS programme.

2. The *Balwadi* Nutrition Programme, also begun in 1970, targeted children between 3 and 6 years of age in rural areas. Four national level organisations, including the Indian Council of Child Welfare, were given grants to implement the programme through *balwadi*s. The food supplement received was equivalent to 300 kcal and 10 g of protein / day.

3. Integrated Child Development Services (ICDS) has a strong nutrition component in the form of supplementary nutrition, vitamin A prophylaxis, and iron and folic acid distribution. The beneficiaries are preschool children below the age of 6 years, pregnant and lactating mothers. Currently ICDS projects are functioning in 5320 blocks all over the country. Children in the age group 3 to 6 years attend *anganwadi*s, where each child is supplied with 65g of energy-rich packed food thrice a week and cooked food with rice, dal, oil or jaggery four times a week. Children in the age group of 6 months to 3 years receive energy-rich packed food once in a week at the rate of 80 g / day. Each antenatal mother receives 1 kg rice, 200 g of green gram, 250 g of packed energy-rich food once a week, from the 3rd month of pregnancy up to 6 months after delivery. Children and mothers receive iron and folic acid tablets, and vitamin A supplements.

4. The Mid-day Meal Programme in schools was set up in 1961, where government and municipal schools supply lunch to needy children, providing at least one third of the daily calorie requirement of the child.

The prevalence of severe form of protein energy malnutrition in India which was in the range of 18 to 20 % in the decade from 1965 to 1975 declined to 5 % by 1980–86 (UNICEF 1989).

7.5.3 Iron and Folic Acid Deficiency

Iron is a micronutrient, which plays a major role in the nutrition of humans. The main function of iron is the formation of haemoglobin in the red blood cells of the body, which combines with oxygen and transports it to all the parts of the body. Folic acid is a component of vitamin B complex. Deficiency of iron and folic acid has been a major nutritional problem in India, especially in rural India.

Table 7.14 Dietary Iron Intake in Rural India

Item	1983	1999-2000
Average iron intake per capita per day in rural India	26.1 mg	22.4 mg
Percentage of households with below RDA intakes	65	83

Source: Sharma and Meenakshi (2004)

Given that the recommended daily allowance of iron / day / person is 28 mg, it is alarming to find that the average intake in rural areas is not only lower than this but has also deteriorated drastically over the 1980s and 1990s.

In the Fourth Five Year Plan (1969–1974) the government launched the National Nutritional Anaemia Prophylaxis programme. The objective of this programme was to supply iron and folic acid tablets to children below 12 years of age and pre- and post-natal women. The exact period of supplementation of tablets depended on the severity and progress of the disease in the beneficiaries. An anaemic child was given a tablet containing 20 mg of elemental iron (i.e., 60 mg of ferrous sulphate) and 0.1 mg of folic acid per day. All pre- and post-natal mothers received a tablet containing 60 mg of elemental iron (i.e., 180 mg of ferrous sulphate) and 0.5 mg of folic acid.

Table 7.15: Anaemia among Women and Children, All India, 1998-99

Type of anaemia	Among children (6-35 months)	Among women (ever married)
Mild	23%	35.0%
Moderate	46%	14.8%
Severe	5%	1.9%
Total	**74%**	**51.8%**

Source: National Family Health Survey (1998-99)

Maternal mortality rate due to iron and folic acid deficiency anaemia came down from 24.4 % in 1982 to 17 % in 1995. This was achieved in spite of the decline in the dietary intake of iron between 1983 and 1999–2000, indicating the successful implementation of the National Nutritional Anaemia Prophylaxis Programme (Gopalan 2000).

7.5.4 Iodine Deficiency

Iodine is one of the essential nutrients required for the synthesis of the thyroid hormones, which in turn are necessary for the normal mental and physical well being of all humans. The requirement of iodine is 150 mg per person per day. Deficiency occurs when the iodine intake falls below the recommended levels. Till recently, iodine deficiency was equated with goitre. However, apart from goitre, iodine deficiency can lead to a much wider spectrum of disorders: hypothyroidism, retarded physical development, impaired mental functions, increased rate of spontaneous abortion, still birth, neurological cretinism, deaf mutism, dwarfism and severe mental retardation.

Iodine deficiency disorders in India are a major national problem with socio-economic consequences. In the 1960s, it was estimated that there were about 9 million persons affected by goitre in the Himalayan goitre belt (Doraiswamy 1969). An ICMR study in 1989 showed that in 9 States outside the traditional goitre belt, overall goitre prevalence was 21.1 % and that of cretinism was 0.7 %. An estimated 167 million persons were exposed to the risk of iodine deficiency disorders. Out of them 54 million had goitre, 2.2 million had cretinism and 6.6.million had neurological disorders (Government of India, 1992–93).

A study conducted in the Kangra valley of Himachal Pradesh showed that iodine deficiency was the most common cause of goitre and that the consumption of iodised salt on a regular and continuous basis reduced the prevalence of goitre. On the basis of this study, the government initiated its National Goitre Control Programme (NGCP) in 1962 in a few selected goitre endemic districts. These districts were supplied with iodised salt. A review at the end of two decades showed that the prevalence of goitre remained high due to insufficient production of iodised salt and lack of awareness among the population about the benefit of iodised salt. In 1983, the government decided to go in for universal iodisation of salt. It was proposed that common salt be replaced with iodised salt in a phased manner by 1992. In June 1992, NGCP was appropriately re-designated as the National Iodine Deficiency Disorders Control Programme (NIDDCP) and nation-wide use of iodised salt was promoted.

6. Conclusion

The discussion so far has elaborated the efforts that have been taken by the state in combating the primary health problems faced by our people. National programmes dealing with specific diseases have been conceived and implemented resulting in successful outcomes. These programmes combined appropriate technological interventions with suitable managerial systems and we find a definite decline in the incidence of major health diseases over time in the country. The following table provides a summary of the technological and administrative interventions that have been implemented in the country to combat the various diseases afflicting India.

Table 7.16: Technological and Managerial Interventions for Major Diseases, India

Disease	Catalytic technology	Strategic interventions
Communicable diseases		
Malaria	Diagnosis of malaria by microscopic examination of the blood smears of patients after staining with JSB staining method. Presumptive & radical treatment with chloroquine & primaquine; insecticidal spray with DDT	National Malaria Control Programme, 1953 National Malaria Eradication Programme, 1958 Modified plan of operation under NMEP, 1977
Leprosy	Multi-drug therapy by Rifampicin, Clofazimine & DDS	National Leprosy Control Programme, 1955 National Leprosy Eradication Programme, 1983 Modified Leprosy Elimination Campaign, 1997
Tuberculosis	Development of DOTS strategy with multi-drug therapy, Rifampicin the major bacterial drug being one among them; microscopic examination of sputum smear; BCG vaccination.	National Tuberculosis Control Programme, 1962 A Pilot Project of the Revised National Tuberculosis Control Programme, 1993 Revised National Tuberculosis Control Programme Phase I, 1997
Cholera & Diarrhoeal Disease	Oral Rehydration solution and intravenous fluid treatment	National Cholera Control Programme, Fifth Five Year Plan National Diarrhoeal Disease Control Programme, 1978 National Oral Rehydration Therapy, 1986-87
Non-Communicable diseases		
Blindness	Cataract surgery	National Trachoma Control Programme, 1963 National Programme for the Control of Blindness, 1976 Blindness Control Project, 1994-95
Vaccine-preventable diseases		
Small pox	Small Pox vaccine	National Small Pox Eradication Programme, 1962 Surveillance followed by quick containment, 1973
Diphtheria Pertussis Tetanus Poliomyelitis Measles Tuberculosis	Combined Diphtheria, Pertussis, Tetanus vaccine Oral Polio vaccine Measles vaccine BCG vaccine	Expanded Programme of Immunisation, 1978 Universal Immunisation Programme, 1985 Child Survival and Safe Motherhood Programme, 1992 Reproductive and Child Health Programme (RCH), 1997 Pulse Polio Immunisation Programme, 1995
Major Nutritional Deficiency Disorders		
Vitamin A deficiency Protein energy malnutrition	Vitamin A supplementation Low cost energy-rich food	Mid-day Meal Programme, 1961 National Vitamin A prophylaxis programme, 1970 integrated with Child Survival and Safe Mother hood Programme, 1992 Special Nutrition Programme, 1970 Balwadi Nutrition Programme, 1970 Integrated Child Development Service, 1975
Iron and Folic acid deficiency anaemia	Iron and Folic Acid tablets	National Nutritional Anaemia Prophylaxis Programme, 1969
Iodine deficiency disorders	Iodisation of salt	National Goitre Control Programme, 1962 Universal Iodisation of Salt, 1983 National Iodine Deficiency Disorders Control Programme, 1992

In the country as a whole, there has been a definite decline in the incidence of diseases over time. However, it is not possible to estimate the impact of various health programmes on the rural population due to lack of availability of data separately for rural India. Nevertheless, given that 70 % of the Indian population continue to reside in rural areas, the estimate of decline in prevalence of various diseases in the country as a whole will be true for rural areas too. Estimates of Infant Mortality Rate (IMR) and life expectancy at birth are available for rural India separately and these indicators reflect an overall advancement in health in rural India.

Table 7.17: Impact of Various Health Programmes on Specific Diseases

Classification of Diseases	Disease	Indicator	Reference Period	
Communicable Diseases	Malaria	Incidence	75 million in 1947	1.64 million in 2003
	Leprosy	Incidence Rate per 10,000 population	5.9 in 1991	2.3 in 2004
	Tuberculosis	Mortality due to disease	100 per 1 lakh population in 1964	37 per 1 lakh population in 2002
	Cholera	Mortality of reported cases	37 % in 1960	0.07 % in 2003
Vaccine Preventable Diseases	Small Pox	Incidence	84,902 in 1967	Nil in 1976
	Poliomyelitis	Incidence	28,257 in 1987	268 in 2001
	Diphtheria	Incidence	12,952 in 1987	4954 in 2001
	Pertussis	Incidence	1,63,786 in 1987	28,900 in 2001
	Neonatal Tetanus	Incidence	11,849 in 1987	1354 in 2001
	Measles	Incidence	2,47,519 in 1987	45,301 in 2001

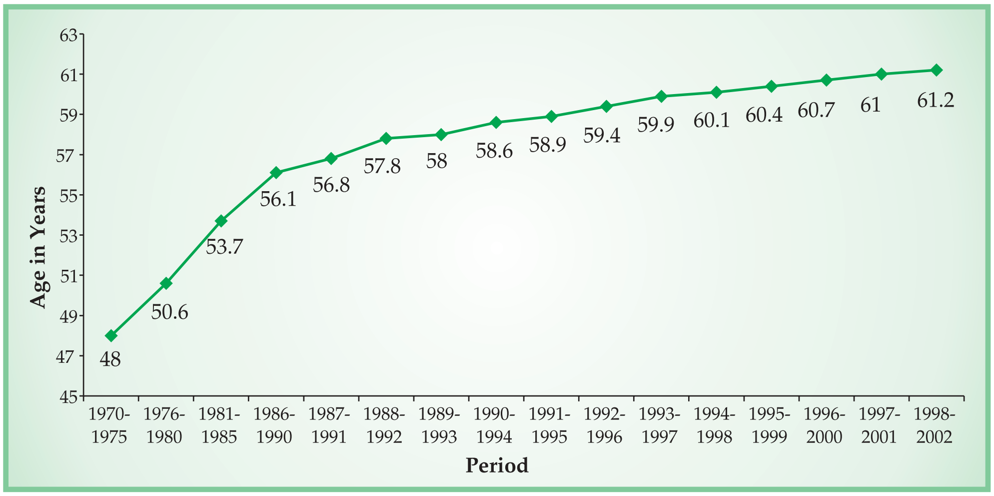
Infant mortality rate is considered a sensitive indicator of the socio-economic conditions of a population. IMR is influenced by medical as well as non-medical factors. The level and quality of medical care available for deliveries as well as for ante-natal care, the reach of the immunisation programme, the nature of nutritional interventions made available for pregnant women, availability of safe drinking water and sanitation, all these factors particularly influence IMR. From the table below the decline in IMR over three decades is clear. The universal immunisation programme is perhaps the most important medical intervention in bringing about a decline in IMR in rural India. The indicator, life expectancy at birth, is influenced to a very large extent by decline in mortality rate in general and infant mortality rate in particular, decline in incidence of diseases and improvement in sanitary conditions. Therefore, the improvement in life expectancy of an average villager in India may be taken as a summary measure of achievements in overall health status of population. Life expectancy at birth, of the average rural Indian was 48 years during 1970-75 and increased to 61.2 years by 1998-2002.

Table 7.18: Infant Mortality Rate, Rural India

Year	IMR in Rural India
1971	138
1981	119
1991	87
1992	85
1993	82
1994	80
1995	80
1996	77
1997	77
1998	77
1999	75
2000	74
2001	72
2002	69

Source: Ministry of Health and Family Welfare (1999); www.indiastat.com

Figure 7.2: Life Expectancy at Birth, Rural India



Source: Ministry of Health and Family Welfare (1999); www.indiastat.com

Using the life expectancy at birth as an indicator of technology achievement in the sphere of health (and equating the value of 1970–75 to 100), the technology achievement index has moved from a value of 100 in the early 1970s to 128 by the late 1990s.

While the discussion in this chapter clearly brings out the improvement in health in the post-Independence period in India, it is important to note that the achievements are far from adequate.

REFERENCES

Barua. 1978. *Souvenir*. 33rd National Conference on Tuberculosis and Chest Diseases, Bhopal.

Basu, R.N. 1981. *Indian Paediatrics* 18(8) 507. Cited in Park, 1991.

Doraiswamy, P.K. 1969. *Swasth Hind* 12:21. Cited in Park, 2000.

Government of India. 1986. *Swasth Hind* 30(8) 177, Central Health Education Bureau. Cited in Park, 1991.

———. 1987. "Centre Calling". November 1987. Cited in Park, 2000.

———. 1992. *Present Status of National Programme for Control of Blindness.* New Delhi: Directorate General of Health Services.

———. 1992–93. *Annual Report 1992–93*. New Delhi: Directorate General of Health Services. Cited in Park, 2000.

———. 1994. *Health Information of India, 1994*. New Delhi: Directorate General of Health Services. Cited in Park, 2000.

Ministry of Health & Family Welfare, Government of India. 1983. *Health Statistics of India.* New Delhi: Central Bureau of Health Intelligence.

———. 1999. *Compendium of India's Fertility and Mortality Indicators, 1971–1997*. New Delhi: Registrar General, Department of Family Welfare.

———. 2000. *Annual Report 1999–2000*. New Delhi

———. 2003. *Annual Report 2002–03.* Cited in Park, 2005.

———. 2004. *Annual Report 2003–04.* Cited in Park, 2005.

———. *Annual Reports* (various years). New Delhi.

National Family Health Survey (NFHS 2). 1998–99. *State Reports*. Mumbai: International Institute for Population Sciences (IIPS) and Maryland, USA: ORC. Macro (various issues).

Park, K. 1991. *Park's Text Book of Preventive & Social Medicine*. Jabalpur: Banarasidas Bhanot.

———. 2000. *Park's Text Book of Preventive & Social Medicine*, 16th Edition. Jabalpur: Banarasidas Bhanot.

———. 2005. *Park's Text Book of Preventive & Social Medicine*, 18th Edition. Jabalpur: Banarasidas Bhanot.

Park, K. and J.E. Park. 1977. *Text Book of Preventive & Social Medicine.* Jabalpur: Banarasidas Bhanot.

Ramachandran, R. 2006. "Malaria malpractice". *Frontline*, 23 (12).

Sharma, Rekha and J.V. Meenakshi. 2004. "Micronutrient Deficiencies in Rural Diets". In M.S.Swaminathan and Pedro Medrano (eds). *Towards Hunger Free India: From Vision to Action*. Chennai: East West Books.

UNICEF. 1989. *The State of The World's Children 1989*. New York: Oxford University Press.

WHO. 1972. *WHO Chronicle*, 26, 393. Cited in Park, 1977.

———. 1976. *Wkly Epidem.Rec.*: 51.62. Cited in Park, 1977.

———. 1977. *WHO Chronicle* 31:3. Cited in Park, 1991.

———.. 1978. *Expanded Programme of Immunisation.* Report and Working Papers of the Technical Discussions, Mongolia, 22-28 April 1978. New Delhi: WHO South East Asia Regional Office (SEARO).

———. 1980. *The Global Eradication of Small Pox, Final Report*. Geneva. Cited in Park, 1991.

———. 1981. *Wkly Epidem.Rec*. 56 (43) 337-344. Cited in Park, 1991.

———. 1998. *Tech. Report Ser. No. 874.* Cited in Park, 2000.

———. 1999. *Health Situation in South East Asia Region 1994-1997*. New Delhi: WHO SEARO. Cited in Park, 2000.

———. 2000. *Joint Tuberculosis Programme, Review, India*. New Delhi: WHO SEARO. Cited in Park, 2000.

www.cde.govt / mmwr / preview / mmwrhtml / mm511102.htm-23k

www.indiastat.com

8

DRINKING WATER*

8.1 Introduction

Availability of drinking water, an essential commodity for the existence of life, continues to be a major problem across the villages of India. Till the early 1950s, open dug wells and surface water sources were the traditional water resources in rural India and these often dried up in the summer months. Several attempts have been made by the Central and State governments to provide safe drinking water to people across the country. Yet, the challenge of providing the minimum required quantity of safe drinking water at a location close enough to habitations remains to be met in most rural areas. Groundwater, which continues to be the predominant source of rural water supply in India, is often contaminated with natural geo-chemicals like fluoride, iron, arsenic and man-made sources of pollutants such as nitrate, heavy metals and organics. Provision of safe drinking water that is free from biological contamination (guinea-worm, cholera, typhoid, etc.) and chemical contamination (excess fluoride, brackishness, iron, arsenic, nitrate, etc.) to all rural habitations continues to remain a challenge in India.[1] (Meenakshisundaram 2003)

This chapter traces the progress in the provision of safe drinking water to habitations in rural India and analyses the role of technology in the rural water supply programmes. The areas where there is lack of adoption of available technology and areas where there is a need for new technology have also been identified. In analysing the progress in rural drinking water supply programmes in India, one encounters several gaps in records because of lack of systematic data collection systems, particularly for the period prior to 1992.

8.2 Drinking Water Supply in Rural India

In the evolution of drinking water supply programmes in rural India, four distinct stages can be identified on the basis of the pace at which villages were covered with water supply schemes and the focus of these schemes. The four time periods are 1947–66, 1966–80, 1980–86 and 1986–present. The first stage was practically a dark phase, when, in spite of water supply and sanitation being added to the national agenda during the First Five Year Plan period, financial support provided by the government towards development of drinking water supply was meagre (Planning Commission report, quoted by Black and Talbot 2005). The basic groundwork for a major drinking water supply programme was laid in 1962. The Ministry of Health had undertaken the first survey to identify 'problem villages' — a definition then used to describe communities that were water scarce. Criteria for identifying problem villages, which is still being used, were fixed during the 1962 survey: villages without year-round water supply within 1.6 km distance on the plains and within 100 m elevation on the hills.

It was during 1966–68, when India experienced severe drought, that the government took some serious measures to combat the rural drinking water shortage. The emergency help from UNICEF during this

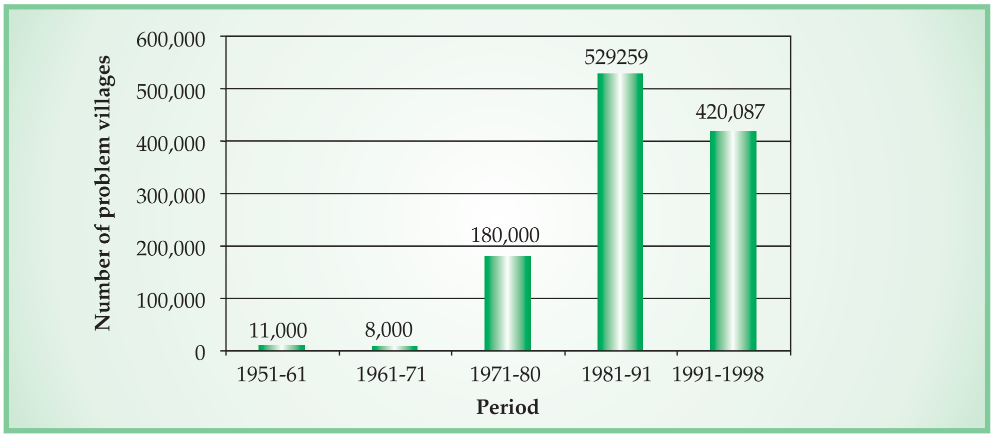
*Contributed by Dr. Indumathi M. Nambi, Assistant Professor, Indian Institute of Technology, Chennai.

[1] Habitation is a locality within a village where a cluster of families resides.

period is a noteworthy landmark in the history of India's rural water supply programme. UNICEF airlifted 11 drilling rigs from the United Kingdom that could reach groundwater located deep below the hard rock terrain (Black and Talbot 2005).The success of this technology in the drought-prone regions marked the beginning of an era of high speed drilling. One hundred and twenty-five drilling rigs, which could each drill at the rate of 100 bore-holes per year were brought in from the United Kingdom. Out of 5,76,000 revenue villages, 1,13,000 villages were identified as problem villages in 1974 and most of them were in the hard rock areas (http://planningcommission.nic.in 2005). Meanwhile, another government survey completed by 1972 had included water quality in its identification of problem villages. This brought in more villages under the category and the number of problem villages went up to 3,25,000 in spite of the improved coverage in the previous years. A centrally-funded scheme for accelerated rural water supply was implemented from 1972 to 1977, and drilling was made the cornerstone of the water supply programme. This programme gave full assistance to the States and centrally-administered territories to extend water supply to acute problem villages located in hard rock regions, with particular attention to underprivileged castes and tribes. By 1980, 94,000 bore-hole hand-pumps were installed, theoretically reducing the number of problem villages to 56,000. But a new government survey prior to the Sixth Plan revealed that there were 2,31,000 problem villages in 1980 (Black and Talbot 2005). The increased figure was due to the inclusion of water quality criteria, improved surveying, falling water tables and inadequacy of existing wells. In terms of percentage, less than 31 % of rural areas were fully covered by the year 1980.

1980 marked the launching of the International Drinking Water and Sanitation Decade. India's Sixth Five Year Plan (1980–85) allocated about 4.6 % of its public sector outlay, a significant portion of its budget, to tackle water problems in rural India (Economic Surveys 1980–85). However, till 1985–86, more than 50 % of the plan expenditure on water supply and sanitation was allocated for urban areas. It was only during the Seventh Five Year Plan period that more than 60 % of plan expenditure was assigned specifically for rural areas (www.planningcommission.nic.in/data/dataf.html).

Figure 8.1: Rural Water Programmes: Number of Problem Villages Covered



Source: www.planning commission.nic.in/data/dataf.html

Figure 8.1 shows the growth in rural water supply coverage in terms of the number of problem villages covered.[2] During the Sixth Plan, 1,90,000 problem villages were provided with safe water, while during the same period 1,21,000 additional problem villages were identified (ibid). The increase in coverage of

[2] As regards 'problem areas', till 1992 data refers to villages and since 1992 data refers to habitations. Given this, the data on percentage of problem areas covered is not comparable over time.

problem villages since the 1980s is due to various measures taken by the state to address the issue of lack of drinking water in villages.

The efforts of the Central and State governments were also backed by international organisations such as the bilateral agencies of Japan, the United Kingdom, the United States, Denmark, Sweden, Germany, Australia, Netherlands, etc., and multilaterals such as the World Bank, WHO, UNICEF (Water and Sanitation Programme-South Asia) UNDP, and the European Union. These external support agencies (ESA) have made invaluable contributions to the sector in terms of sustaining demonstration and experimentation at the project level, research, introduction of technological innovations, etc.

In 1986, the National Drinking Water Mission, which was later renamed as the Rajiv Gandhi National Drinking Water Mission (RGNDWM), was launched. This accelerated the pace of several programmes by providing a renewed form of mission approach for implementation. In 1999, a separate department was created for 'drinking water supply' under the Ministry of Rural Development. In 1998, the Mission commissioned a monitoring and evaluation study through survey methods in 13 States.[3] The surveys, which were completed in 2000, showed that the percentage of habitations that had been fully covered was 83 %, partially covered was 15 %, and not covered was 1.83 %. The States that were lagging behind were identified and were directed to initiate corrective measures. It was proposed that these figures would be brought to 96 %, 3.5 % and 0.003 % respectively, by the end of 2006 (www.rural.nic.in/rgndw.htm).

Table 8.1: Coverage of Rural Drinking Water Supply, India

Year	Number of Habitations			
	Not covered	Partially covered	Fully covered	Total
1992-93	2,218	32,142	13,88,304	14,22,664
1993-94	472	41,016	13,81,176	14,22,664
1994-95	23,456	47,388	13,51,820	14,22,664
1995-96	41,748	51,524	13,29,392	14,22,664
1996-97	46,153	53,498	13,23,013	14,22,664
1997-98	31,584	85,410	13,05,670	14,22,664
1998-99	38,065	2,68,496	11,16,103	14,22,664
1999-00	11,866	62,770	13,48,028	14,22,664
2000-01	6,673	61,975	13,54,016	14,22,664
2001-02	3,909	40,831	13,77,924	14,22,664
2002-03	9,652	1,01,399	13,11,242	14,22,293
2003-04	5,738	66,845	13,49,710	14,22,293
2004-05	4,588	50,479	13,67,236	14,22,303

Note: Under the Accelerated Rural Water Supply Programme, the following norms are being adopted for providing drinking water to rural population in the habitations:

- 40 litres per capita per day (lpcd) of safe water for human beings
- 30 lpcd additional for cattle in the desert development programme areas
- One hand-pump or stand post for every 250 persons
- The water source should exist within 1.6 km in the plains and within 100 m elevation in the hilly areas

A habitation is considered 'fully covered' if the above norms are satisfied. Habitations which have a safe drinking water source point within 1.6 km in plains and 100 m elevation in hill areas but the capacity of the system ranges between 10 to 40 lpcd are categorised as 'partially covered' (PC) and those having less than 10 lpcd are categorised as 'not covered' (NC).

Source: RGNDWM (Annual Reports)

[3] The evaluation was done by the Indian Institute of Rural Management (IIRM), the All India Institute of Hygiene and Public Health (AIIHPH), Calcutta; Media Research Group, New Delhi; and the Water and Power Consultancy Services (India) Limited (WAPCOS), New Delhi.

From **Table 8.1** it is clear that the percentage of habitations fully covered fluctuates a great deal over the period 1992 to 2005. The period between 1992 and 2000 saw the figures falling in spite of specific interventions by the Central and State governments in this regard. This was due to the slippage of the habitations which had been fully covered into the partially covered and not covered category. Two main causes for the sliding back of covered habitations were identified: first, frequent breakdowns of hand-pumps and lack of proper maintenance and support systems; and second, the heavy dependence on the rapidly depleting groundwater sources that were being used heavily for irrigation purposes. The neglect of traditional practices like protection of catchment areas and rainwater harvesting has also added to the problem. It was estimated that groundwater levels fell by more than 4m during the period 1981–2000. This also led to the emergence of water quality problems in regions with arsenic-, iron- and fluoride-bearing rocks and in coastal areas due to saline water intrusion (Planning Commission 2002).

Renewed efforts in terms of funding and technology since 2000 have brought about an increase in number of habitations fully covered. The villages, which were prone to slipping back due to water table fluctuations, were provided with deeper borewells and piped water supply schemes. Water quality problems were addressed by the State departments with treatment units and supply of alternate surface water sources (www.twadboard.com). These efforts were backed with schemes for rainwater harvesting structures and catchment area protection, to ensure sustainability of water resources.

Table 8.2: Percentage of Households with Safe Drinking Water, India

Year	Percentage of households with safe drinking water
1985	56.3
1990	73.9
1995	82.8
1998	92.5
1999	98.0

Source: Economic Survey (1996 and 2005)

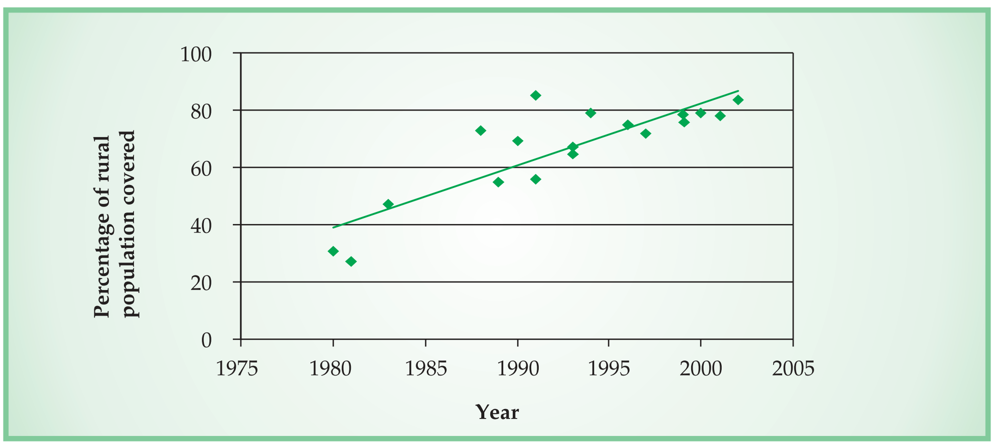
Table 8.2 indicates rapid growth in coverage of rural drinking water supply from 56.3 % of households in 1985 to 98 % of households by 1999. The introduction of borewell drilling technology improved the coverage in previously inaccessible areas and the advent of new and more durable hand-pumps enabled the reductions in this coverage. A summary of data from various sources indicate considerable achievement in rural drinking water supply over the two decades since 1980.

Table 8.3: Percentage of Rural Population Covered by Drinking Water Supply Programmes, India

Year	Percentage of Rural Population Covered	Data Source
1980	31.00	WHO 1984
1981	27.00	CENSUS 1981
1983	47.00	WHO 1986
1988	73.00	WHO 1990
1989	55.00	NSS 1989
1990	69.00	WHO 1992
1991	85.00	WHO-World Bank Joint Monitoring Programme
1991	56.00	CENSUS 1991
1993	64.40	Demographic and Health Survey 1992-93
1993	67.30	NSS 1993
1994	79.00	WHO-World Bank Joint Monitoring Programme
1996	74.80	NSS 1996
1997	72.00	IIMC 1997
1999	78.40	WHO 1999
1999	75.40	National Family Health Survey 1999
2000	79.10	Multi-Indicator Cluster Survey
2001	78.10	Census 2001
2002	83.70	World Health Survey 2002

Source: WHO / UNICEF (2001, updated on the web in 2004)

Figure 8.2: Growth in Rural Drinking Water Supply, Various Sources



Source: Table 8.3

A study sponsored by the World Bank and UNICEF reports that not only is coverage of drinking water supply in rural India inadequate, but also highly imbalanced, varying widely across the country (Planning Commission 2002). According to this study, of the 35 States and Union Territories in India, only Bihar, Chattisgarh, Madhya Pradesh, Tamil Nadu, Uttar Pradesh, Daman & Diu, Delhi, Lakshwadeep and Chandigarh have achieved full coverage of rural habitations. The per capita water supply also ranges from a low of 9 lpcd to a high of 584 lpcd.

8.3 Role of Technology in Increasing Rural Water Supply

8.3.1 Drills and Pumps

The role of technology is significant in the expansion of drinking water supply coverage in rural India. Given that groundwater is an important source of supply in the various drinking water supply programmes, technologies related to drilling have played an important role in this regard. Initially, in hard rock areas, pneumatic powered 'down the hole' (DTH) hammer drills were used for drilling borewells. However, due to caving in of soil in some areas the DTH drills were not suitable, and hydraulic powered rigs were introduced. These rigs could drive large bore-holes for inserting a casing and could successfully reach greater depths in hard rock areas. Constant improvisations were made to the design of drilling rigs to make them more versatile for a wide range of geological conditions. Different components such as compressors and power supplies were mounted separately so that they could be interchanged with higher capacity units depending on the requirements of the site. A new design of two small truck-mounted rigs was developed to improve manoeuvreability in remote rural areas. This indigenous design became a great success and was established as the standard drilling machine from 1984 (UNICEF 2000).

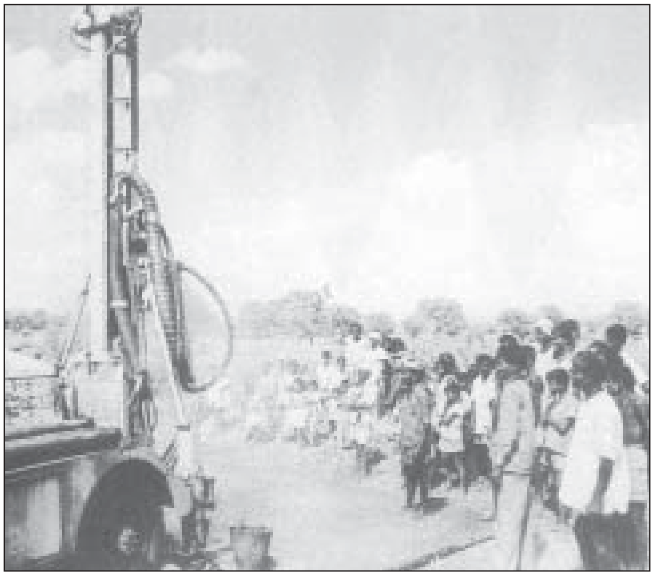


Photo 8.1: One of the Early Drilling Rigs

The indigenous input to the success of the bore-hole hand-pump revolution is the development of a reliable deep well hand-pump. The cast iron pump originally designed for family use could not withstand the heavy demand at community water sources with continuous pumping for 10 to 12 hours a day. In 1974, a survey showed that only 25 % of the hand-pumps worked at any given time (Black and Talbot 2005). Sturdy design, access to deep water tables, lighter pumping, and low cost were the main features of the new pump. The new elements were indigenously designed and incorporated into the existing Sholapur pumps and also manufactured in the country by Richardson & Cruddas, Chennai. The India Mark II (IM II) hand-pump was immediately put to test in 1977 and became an immediate success because of its performance. By 1984, 6,00,000 pumps were installed and by 1998, 3 million pumps were in operation. The Mark II pump received the seal of high international approval by the UNDP / World Bank hand-pump testing programme. The downtime of pumps, i.e., the period when it could not be used due to breakdowns was estimated to be around 37 days per annum (Black and Talbot, 2005). The breakdown of Mark II pumps was primarily due to swelling of the leather piston seal and jamming of the cylinder. To reduce the downtime, a localised, and easy to maintain and repair, system was required. A system of village level operation and maintenance (VLOM) concept was introduced where the maintenance work could be done by trained women within the community rather than relying on a centralised facility. With the introduction of the VLOM scheme by the rural drinking water supply department in the 1970s, came the need to develop sturdy pumps with longer lifetimes and which were easy to repair by local village women. In the late 1980s, with the collaborative efforts of UNDP and the World Bank, Mark III pumps were developed and tested. The design modifications included wider rising main so that the piston could be removed without removing the rising main and the use of durable nitrile rubber for seals rather than leather ones. Mark III pumps cost more than Mark II pumps but they had significantly lower operation and maintenance costs. The development of Mark II and Mark III pumps were major contributions of technology not only for the Indian rural water supply programmes but also throughout the developing world.

Photo 8.2: Mark II Pump

8.3.2 Geophysical Investigations

Unscientific practices adopted in identifying bore-hole locations lead to failure of the rural water supply system. The capacity of the borewell is determined by the quantity of water that can be pumped out before the hole goes dry and is expressed as litres extracted per day. The hydrogeology of a region is a major deciding factor of the capacity of wells. There are several techniques such as electrical resistivity method, seismic method, etc., which can enable mapping of groundwater resources in a region. These maps can be used to identify the precise location and depth of the borewell which can yield the maximum capacity. Without the proper utilisation of these technologies, the drilling and hand-pump technologies are of no use. Particularly in the case of expensive hard rock drilling, scientific methods of identification of bore-hole locations becomes invaluable. In order to have a systematic geophysical survey, a variety of geophysical instruments such as electrical well loggers, terrameters and magnetometers have been adopted since 1985 for groundwater prospecting, and engineers and geologists have been trained. With the success of identifying high yielding borewells, geophysical investigations became a routine part of site selection and an estimated 2,10,000 bore-holes have been drilled annually with an average success rate of 85 % (Black 2000). A comparative study of failed hand-pumps in several States was performed by UNICEF to assess the impact of geophysical investigations (UNICEF 1995). It was found that Tamil Nadu which had preceded drilling with geophysical investigations showed a success rate of 97 %, whereas Maharashtra and Madhya Pradesh where ad hoc drilling based on random selection or community convenience was done, the rate of dry bore-holes was as high as 40 % (Black 2000). In some northeastern regions, notably Mizoram, the introduction of geophysical surveying has made it possible to locate high yielding borewells where previously all efforts had been unsuccessful.

8.3.3 Remote Sensing and GIS Technology

Remote sensing and GIS have emerged as powerful technological tools to identify the location of drinking water wells and also rainwater harvesting structures. India has been launching its own remote sensing satellites and a large amount of ground facilities and infrastructure has also been established to generate quality information regarding the hydro-geology of any part of the country. Several States have adopted remote sensing and GIS as tools for groundwater prospecting. It has become the starting point in all investigations for drinking water sources. The technology involves overlaying of several maps such as geology, topography, land use pattern, etc., to narrow down on the most probable location for high yielding wells. While the remote sensing / GIS investigations can narrow down the region of high yielding aquifers up to a minimum of 1^2 km, the exact location of borewells within that area has to be identified by geophysical methods (see **Box 8.1**). The Tamil Nadu Water Supply and Drainage Board conducted a detailed study to support the effectiveness of this technology for selection of borewell locations. Between the years 1990 and 1998, the TWAD Board scanned over 92 locations for the presence of high-yielding aquifers (high-yielding are those that can provide water at a rate greater than 100 lpm when pumped).[4] Using remote sensing and geophysical surveying, prospective bore-hole locations in several habitations in each of these 92 places were identified and drilled. The wells were grouped into four categories according to the water yield: low (<10 lpm), medium (10-50 lpm), medium-high (50-100 lpm) and high-yielding (>100 lpm). An analysis of these results indicate that out of the 418 bore-hole locations identified by remote sensing technology, 268 locations (64 %) were high- yielding aquifers, 13 % were medium-high, 17 % were medium-yielding and 5% were low-yielding aquifers. The technology has picked up and currently all the States in India are using this valuable tool for groundwater investigations and also for locating rainwater harvesting structures (www.twadboard.com).

[4] This section is based on data provided by Tamil Nadu Water Supply and Drainage board (TWAD) as well as the discussions we have had with their engineers.

Box 8.1 Remote Sensing and GIS Technology

In Tamil Nadu, remote sensing and GIS technology have been used extensively in all the blocks to delineate favourable zones for groundwater withdrawal and recharge. The process involves overlaying and integration of different themes to delineate areas with different recharge or discharge possibilities, such as highly favourable, moderately favourable, less favourable and poor. The Tamil Nadu Water Supply and Drainage Board (TWAD) has successfully created a digital database for all the 386 blocks of Tamil Nadu for the benefit of the user community including scientists and engineers. These databases can be used:

- to identify groundwater sources with high yields for large water supply projects, particularly in remote areas inaccessible to geophysical surveying
- to recommend suitable methods of recharge depending upon terrain conditions, landforms, availability of water, landuse, soil characteristics, etc.
- to suggest suitable recharge measures near existing power pump sources for the sustainable development of groundwater

Identification of suitable well / recharge locations depends not only on the hydrogeology of the area but also on other factors such as land use, soil type, etc. The systematic methodology of preparing these databases is presented below to highlight the intricacy of the process. The steps undertaken are:

- Collecting existing hydrological / hydro-geological and allied data from various agencies (State / Central / others)
- Analysing long-term water level data and plotting pre- and post-monsoon water level trends, to evaluate the water level fluctuations
- Studying the rainfall pattern of the area to evaluate runoff characteristics and groundwater conditions
- Analysing the satellite data IRS-1C,LISS III, FCC for the preparation of (1) thematic maps on geology, geomorphology, soil (hydrologic soil groups) , slope and land use and (2) derived maps such as lineament density map, depth to weathered thickness map, rainfall isohyets, runoff isolines, water table contour map and drainage density (using Survey of India toposheets)
- Analysing all the thematic maps initially on watershed basis and preparing output maps for individual blocks
- Integrating the thematic maps by giving weightages for different themes using GIS package and classifying the block areas into different zones for recharge / well locations.

8.3.4 Technologies for Sustainability of Resources

A substantial achievement has been made in providing drinking water coverage for rural areas with borewells, pumps and piped water supply schemes. Almost 80 % of them rely on groundwater sources and the remaining on surface water sources. Recent surveys (Planning Commission 2002) indicate that during the summer months, at least 25 % of these borewells run dry, thus questioning the sustainability of these systems. Inadequate rainfall and competing irrigation water requirements have resulted in groundwater depletion. As the discussion pertaining to **Table 8.1** indicated, a large number of habitations do slip back to the 'not covered' and 'partially covered' categories during the summer months defying the sole objective of the drinking water mission. Hence, ensuring sustainability of the sources is crucial for the success of the mission. In order to tackle this problem, submissions under the Rajiv Gandhi National Drinking Water Mission have been launched for water conservation and rainwater harvesting. Five per cent of the Accelerated Rural Water Supply Programme (ARWSP) has been earmarked for submission on sustainability. Artificial recharge of groundwater and rainwater harvesting has been given top priority by all departments concerned with water. In addition, restrictions have been placed on drilling wells without prior approval. Recently CGWB has issued orders that all drilling for groundwater extraction should be approved by the concerned State's water resources department. This will ensure that no irrigation well can be drilled deeper than drinking water wells located within the zone of influence.

8.3.4.1 Artificial Recharge of Groundwater

Aquifers are generally considered sources of water but they can also serve as large underground storage reservoirs. Artificial recharge may be viewed as an augmentation of the natural movement of surface water into underground formation by methods of construction, by surface spreading of water, or by artificially changing natural conditions. The purpose of artificial recharge of groundwater is to reduce or reverse declining levels of groundwater in a basin. In a hard rock groundwater basin, it is common to find a fractured zone underlying a weathered zone. Surplus water is often stored within such zones. The zones can be recharged economically through a single injection well, provided the well goes through both the layers. In regions with no perennial source of water, streams often dry up in the post-monsoon season. To avoid this, the base flow of a stream can be augmented by recharging groundwater at locations far away from the stream so that the recharged water will reach the stream during periods of low flow.

Assessment of the quantity of water which is recharged in the individual layers and determination of the part of the recharged water that is available in the zone of interest at any time are important tasks. GIS, remote sensing, and both stable and unstable radio isotopes have been successfully used to identify recharge zones. Once the optimum recharge zones are identified, percolation tanks are created by constructing small earthen dams across a natural stream. They are located upstream of an existing cluster of dug wells. The surface runoff during the short monsoon period is collected in the tanks. Under favourable soil and rock conditions, the water percolates and recharges the groundwater. The effectiveness of percolation tanks in recharging groundwater have also been studied using the isotope method (see **Box 8.2**).

Box 8.2 Application of Isotope Technology in India — A Case Study

The use of environmental stable and unstable isotopes, artificial radioisotopes and sealed radioactive sources has a wide variety of applications including characterising water masses and origin of water, seawater intrusion, interconnection of water bodies, soil moisture movement and groundwater recharge, seepage/leakage from reservoirs/canals, water balance and dynamics of lakes, groundwater salinisation, characterisation of geothermal waters, stream flow measurements, sediment transport, and dating of groundwaters. These studies have been mainly carried out in parts of Andhra Pradesh, Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Pondicherry, the Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh and West Bengal (Kumar and Seth 2000).

Application of isotope techniques are based on the general concept of tracing in which either intentionally introduced or naturally occurring isotopes are employed. The most commonly used ones are deuterium, tritium, oxygen and carbon. The ratio of the isotopes in the natural precipitation varies seasonally and with altitude. Also, rainwater undergoes changes in its isotope composition due to evaporation as it flows through the top soil. Precipitation being the only source of recharge to naturally occurring springs in mountainous regions, the origin of the spring water can be easily tracked and dated by analysing the isotope fractions. It will also be possible to differentiate river water fed by precipitation in the higher altitudes, true springs connected to underground aquifers, and seasonal springs fed by topsoil water using these techniques. A study (Shivanna et al 2005) was conducted by scientists at the Bhabha Atomic Research Centre in Gaucher, Uttaranchal to identify recharge zones of the frequently drying springs in that region using isotope tracer techniques. Water samples were collected from existing springs at different altitudes and were analysed for stable isotopes, Deutrium ^{2}H and ^{18}O. After thorough investigation, it was identified that the springs in the region were not true springs but mainly seepage waters draining from higher altitude to the lower altitude through the topsoil zone. It was also determined that the groundwater circulation was rapid and that the springs were sustainable for a period of four to five months after the monsoon. The possible mixing pattern of groundwater between different valleys in the region have also been identified. Such information along with the identification of fissures and faults using geophysical probing or remote sensing will enable precise identification of artificial recharge zones.

8.3.5 Water Quality

The quality of the water has also been deteriorating in some of the States due to natural and anthropogenic causes. A water quality assessment performed by CGWB in 2002 has highlighted that groundwater which contributes to 80 % of the total drinking water supplied is at a high risk of contamination by natural and man-made sources. The first water quality survey was undertaken in 1991 by the Rajiv Gandhi National Drinking Water Mission, the results of which were validated and updated in 1999**.** A subsequent survey initiated in 2000 provided results in 2004. The presence of excess fluoride, arsenic, iron, salinity and nitrate in groundwater, both due to geologic origin and human interventions, lead to serious problems in water quality. West Bengal is the worst affected with 65,156 habitations polluted by iron, arsenic, salinity and fluoride (RGNDWM 2005). Rajasthan, Orissa and Karnataka are also critical

States with at least one of the parameters not within the permissible limit. Tripura, Assam and Gujarat come next, with close to 10,000 affected habitations. Andhra Pradesh, Tamil Nadu Madhya Pradesh, Uttar Pradesh and Chattisgarh have close to 5000 habitations with poor water quality (RGNDWM 2005). Several measures have been taken to improve the quality of water. Some of these interventions are discussed below.

8. 3.5.1 Eradication of Guinea-worm

Guinea-worm disease is a water-borne infection caused by *Dracunculiasis medinensis*, a female nematode. The cycle of infection begins when the larvae released into water by an infected person are eaten by cyclops present in the water. When this untreated water is consumed, the cyclops die in the human stomach but the parasite migrates to the subcutaneous tissues. Over several months, it matures into a worm of up to one metre length and after 10 months, it begins to emerge from the body through the skin, creating an excruciatingly painful ulcer. The patient seeks relief by immersing the ulcer in water, which allows the worm to release thousands of new parasites into the water, which in turn is ingested by the cyclops, thus completing the cycle. The incidence of guinea-worm disease has been mainly concentrated in Rajasthan and Madhya Pradesh, particularly in the summer months when water is scarce.

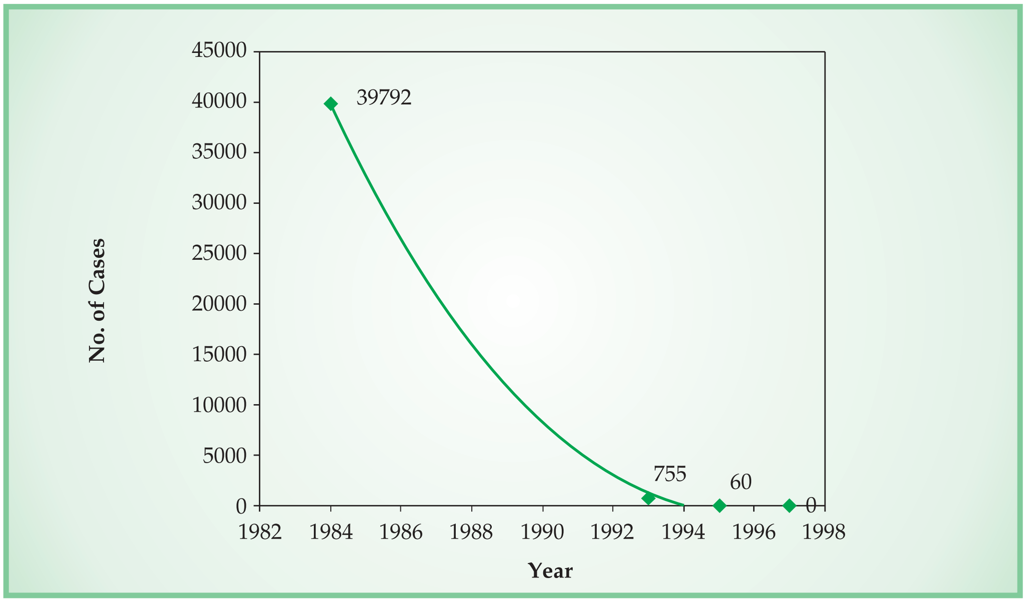
The interventions to control this disease have been multi-pronged, including using technology, raising awareness, and imparting education on hygiene and behavior modification.

The technological interventions included conversion of open access step-wells to covered sanitary wells. Interventions began in the late 1980s and over 2600 step-wells were protected or converted to sanitary wells in two years. Further, 11,000 hand-pump bore-holes were installed to provide alternative protected water supply. In addition the areas adjacent to the wells were paved to prevent the seepage of used water in the vicinity. Regular cleaning and preventive disinfection were undertaken. Conversion to sanitary wells, chemical disinfection of infected waters and open water sources, use of double-sided filter cloths for filtering water were other important interventions which made a difference.

Awareness was generated about the lifecycle of guinea-worms, importance of filtering water and the need to avoid physical contact with infected persons and water bodies. Special camps were organized where ayurvedic doctors who specialised in detection and painless extraction of worms from under the skin were posted and the extraction was done free of charge. Multiple organisations such as National Institute of Communicable Diseases (NICD), RGNDWM, WHO, UNICEF and the health departments of various State governments joined hands to combat this painful disease.

The number of people affected by guinea-worm disease dropped from 40,000 in 1984 to 60 in 1995 (a 99 % reduction over 11 years). Coordinated efforts along with technological solutions to convert step-wells to sanitary wells paid off, resulting in complete eradication of this dreadful disease by 1997. In 2000, India was certified as free from Guinea-worm Disease by WHO’s International Commission for Certification of Dracunculiasis (Planning Commission 2002). The eradication of guinea-worm disease is considered a significant achievement of the Rajiv Gandhi National Drinking Water Mission.

Figure 8.3: Eradication of Guinea-worm Disease



Source: Black and Talbot (2005)

8.3.5.2 Control of Brackishness

With depleting groundwater and inward saline water intrusion, salinity is a problem that has implications for drinking water supply in rural areas. Brackish water or saline water has salinity in the range of 1000-10,000 mg/l. The preferred range of salinity permissible for human consumption is 500 mg/l, though it can go up to1000 mg/l. Excess salinity causes problems with taste and increases cooking time, and also has laxative effects. It is estimated that around 23,500 habitations are affected by excess salinity, most of them in Rajasthan, Karnataka, West Bengal, Maharashtra and Gujarat (RGNDWM 2005).

Water with high salinity can be treated by reverse osmosis, electrodialysis, nano filtration, distillation, solar stills, etc. Between 1992 and 1998, 150 desalination units using reverse osmosis technology have been commissioned in rural areas. The high energy cost involved, routine maintenance such as cleaning and replacement of membranes, and the requirement of skilled people for routine monitoring of the feed water and effluent water have been the limitations to implementing these technologies on a large scale.

Solar stills work on the principle of distillation using solar energy as the heat source. Saline water is let inside an airtight glass enclosure similar to a greenhouse. The black bottom absorbs the solar energy and heats the water, converting it to vapour which condenses and collects in channels along the inner edge of the glass dome. Again, in this technology, the recovery is only 50% and the rest is concentrate which has to be safely discarded. Due to these limitations and the high costs involved, almost 90 % of the affected areas, as indicated earlier, have been provided with alternative piped water supply from distant surface water sources and only 10 % of the affected areas use such small-scale desalination technologies (RGNDWM 2005). These interventions have resulted in a significant reduction (30%) in the number of affected habitations as shown in **Figure 8.4**.

8.3.5.3 Control of Iron

Excess iron has been reported in 1,18,088 habitations mainly in the eastern States of West Bengal, Orissa, Assam, Tripura as well as in Chattisgarh and Karnataka. Consumption of water with iron in excess of the permissible limits of 1 mg/l, results in unacceptable taste and odour, and causes constipation and other physiological disorders (RGNDWM 2005). There are several treatment technologies for removal of iron, the most common ones being aeration and oxidation followed by precipitation. The most effective one is selected and modified to suit the existing water quality in the region. The treatment technologies for iron are low cost and low tech which is the reason why 70 % of the affected habitations are provided with treated local water and only 30 % are provided with alternative water supply from distant sources (RGNDWM 2005). A total of 9355 iron removal plants have been commissioned by the year 2005.

8.3.5.4 Control of Fluoride

Excess fluoride (>1.5mg/l) in drinking water causes dental and skeletal fluorosis, which is a crippling disease. Several effective treatment processes are available such as the activated alumina process and the indigenous Nalgonda process developed by CSIR. Two systems of treatment procedures have been designed: one for use with hand-pumps and the other to be used in open wells and with piped water supplies. In the first, the treatment column is attached to the hand-pump directly; in the second, called the fill-and- draw type, water is passed through chemicals in a container and the treated water is collected in a receptacle placed underneath. Recurring chemical costs, sludge disposal, requirement of a skilled maintenance person and periodical monitoring are the limitations of these technologies.

Photo 8.3: Fill–and-Draw Type Defluoridation Unit

The fluoride problem is prevalent in 17 States and 150 districts of the country, the seriously affected States being Rajasthan, Karnataka, Madhya Pradesh, Gujarat and Andhra Pradesh. Currently 90% of the affected areas are being provided with alternative water supply and only 10% are using water treated through fluoride removal plants (RGNDWM 2005).

8.3.5.5 Control of Arsenic

Arsenic is a serious pollutant which could lead to severe ailments like skin lesions and cancer of several internal organs when taken in excess quantities. It is prevalent in West Bengal, Bihar and Chattisgarh areas — the number of habitations affected was reported to be 5029 in the year 2005, but the number has been rising at an alarming pace that indicates that eradication efforts have had practically no impact.

The current treatment technologies for removal of arsenic to permissible levels of 0.05mg/l include co-precipitation methods and adsorption techniques. Again, as in the case of fluoride, recurring costs of chemicals and adsorbents make these technologies expensive and unsustainable for the rural population. Research is on for identifying low cost, low maintenance systems and a breakthrough is yet to be achieved in developing a universal treatment unit. Current limitations have restricted the interventions to providing 90% alternative supply and only 10% treated water supply (RGNDWM 2005).

8.3.5.6 Control of Nitrate

Nitrate in water sources is due to the effect of anthropogenic activities like agriculture and improper sanitation practices. According to the 2005 RGNDWM report**,** there are 13,958 habitations affected by nitrate and the numbers are rising. There has been no treatment technology adopted for nitrate removal as on date. The interventions have only been by providing alternative supply of water from other sources. Such temporary measures are to stay till a low cost, easy to adopt technology for nitrate removal is put in place.

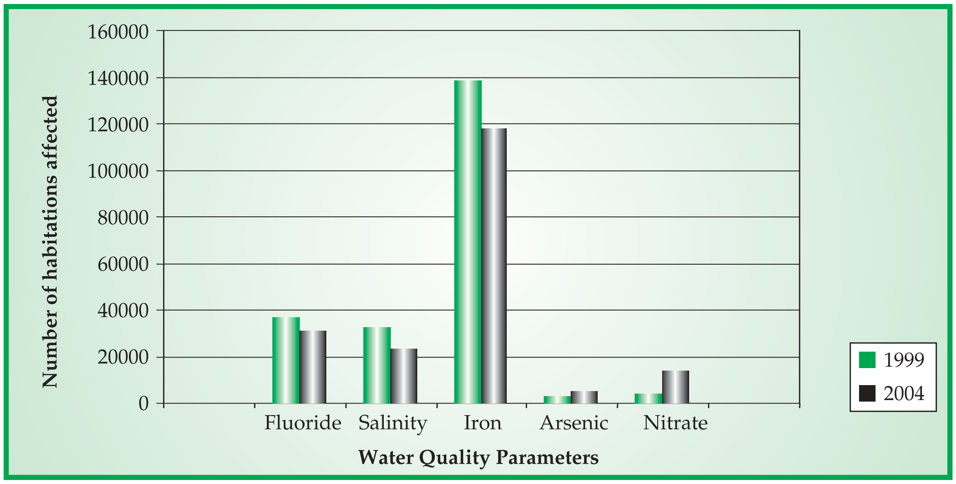
The summary of the achievements in water treatment technologies is presented in **Table 8.4** and **Figure 8.4**. With the limited available data shown, it can be seen that the number of habitations with excess fluoride, iron and salinity has come down but other pollutants like arsenic and nitrate have increased in the affected areas. There is a huge lacuna in policy making regarding treatment of contaminated water. Even in cases where technology is available for treatment, its adoption is limited due to operational constraints. Among the three serious pollutants — arsenic, fluoride and nitrate — fluoride is the most widespread with the health of 62 million people at stake as against 2 million for arsenic (RGNDWM 2005). The figures for nitrate have not been verified yet. Arsenic and nitrate contamination is growing at alarming rates and there is an immediate need to step up efforts to find a low cost, easily adoptable technological solution for these two contaminants.

Table 8.4: Impact of Interventions to Improve Water Quality, India

Parameter	Number of affected habitations		Percentage change
	1999	2004	
Salinity	32,597	23,495	-28
Iron	1,38,670	1,18,088	-15
Fluoride	36,988	31,306	-15
Arsenic	3,136	5,029	+60
Nitrate	4,003	13,958	+249
Multiple		25,092	

Source: RGNDWM (2005)

Figure 8.4: Impact of Interventions to Improve Water Quality



Source: Table 8.4

Box 8.3: Promising Technology: Reverse Osmosis

Tamil Nadu has a long coastline and the groundwater in the towns and villages along the coastal belt is saline due to natural and man-made causes such as overdrawing. There are also no other alternate surface water sources to meet drinking water needs. This has necessitated special programmes such as setting up desalination plants. By 2005, 11 plants covering 360 habitations were completed and commissioned in Ramanathapuram district in Tamil Nadu. One major plant among them is at Narippaiyur with a capacity of 3.0 million litres per day covering 296 rural habitations.

The Narippaiyur desalination plant is the largest in the Indian subcontinent serving a total population of 3,20,187. Reverse osmosis is adopted as the desalination technology here. Reverse osmosis, as the name indicates, is the phenomenon in which the natural osmosis process is reversed by application of pressures. Pressures in the order of 100-1000 psi are applied to force the water through membranes, resulting in the cleaned water being separated from the saline water. This is an energy intensive process and it is necessary to safely dispose the reject water which is highly concentrated with salts. It is ideally suited to coastal areas where it can be integrated to wind energy generators and the reject can be disposed in the sea. Research is currently on to develop more energy efficient systems with reduction in the reject volumes.

Photo 8.4: Narippaiyur Intake Point

Photo 8.5: Reverse Osmosis Plant

8.3.6 Technologies for Monitoring Water Quality

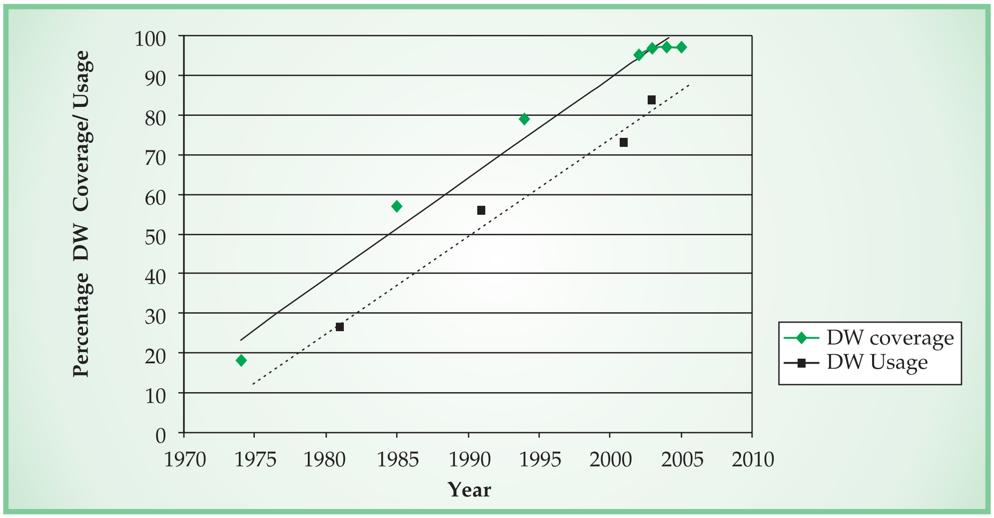
The quality of water varies with the seasons and hence periodic monitoring is an essential component of any water supply programme. It enables performance of risk assessment, identification of hotspots, and optimal targeting of limited resources. Monitoring water quality is quite a challenging task with over 10 million public and private water sources including dug wells, shallow hand-pumps, deep hand-pumps and motorised pumping schemes in the country. The Government of India has sanctioned 450 district level laboratories out of which 252 have been established so far. State governments and other organisations have established 158 labs, making a total of 410 labs in existence currently. In addition 22 mobile labs also operate in some of the States. Although district-level laboratories have been established in the States, not all districts have been covered. Also many of the existing ones lack qualified staff, adequate sample transport facilities, and funds for regular supply of chemicals. In order to overcome these limitations, the Rajiv Gandhi National Drinking Water Mission has been advocating the catchment area approach for testing water quality at the habitation level. Continuous water quality testing at the habitation level using local people requires easy-to-use test kits. The National Chemical Laboratory, Pune and the Defence Food Research Laboratory, Mysore, in cooperation with eight national educational / research institutes, have come up with field test kits for testing water for critical pollutants like arsenic, fluoride, nitrate, and pathogens (Meenakshisundaram 2003). These kits have been tested in the laboratory and in the field for reliability and user friendliness and have proved to be very effective. However, these kits are yet to be adopted on a large scale due to the lack of a proper structure for standardisation, manufacture, marketing, training of community representatives, and record keeping.

In an attempt to institutionalise community-based water quality monitoring and surveillance systems, four pilot projects have been implemented in Nellore, Sehore, Allahabad and Kangra. Capacity building programmes for teachers, social workers and health workers to sample and test water were undertaken along with efforts to raise awareness among people on water quality. After the success of three of these pilot projects, RGNDWM has decided to upscale the initiative by launching a National Rural Water Quality Monitoring and Surveillance Programme (NRWQMSP) at an estimated cost of Rs.600 crore. Action plans from the States are awaited, including details of training programmes and provisions for community contribution, to ensure the long term sustainability of these projects.

8.4 Conclusions

India has the largest rural drinking water supply programme in the world, serving close to 1.5 million habitations and 742 million people. Given the wide geographical spread and hydro-geological complexity of India, it is certainly a huge task to achieve cent percent coverage and the efforts taken by the government in this regard is commendable. The coverage as per the government published data has grown fivefold from 18 % in 1974 to 95 % in 2005 (Black and Talbot 2005). The data reported by other surveys indicate a slightly less figure, around 84 % of rural drinking water coverage (WHO-UNICEF 2001). The gap between the two data sets is because the government sources report the actual installed infrastructure for water supply while the external agencies reveal the ground reality in terms of percentage of habitations with year-round availability of clean water.

Figure 8.5: Gaps in the Utilisation of Drinking Water Infrastructure



Source: Table 8.1 ; Table 8.3; Black and Talbot (2005)

As indicated in **Figure 8.5**, the percentage of rural population provided with infrastructure for drinking water has grown from 18 % to close to a 100 % while the actual usage of this infrastructure for access to drinking water is much less at 84 %. This lacuna is due to several reasons including groundwater depletion and water quality constraints. Irrespective of the difference between drinking water coverage and usage, the growth that has taken place in this sector is quite remarkable. The government is currently focusing its investments into filling this gap. A significant amount of pump breakdown problems have been taken care of with the introduction of Mark III pumps and a strong back-up by village level operation and maintenance schemes for hand-pumps. In many States such as Tamil Nadu, a step further has been taken by replacing all the hand-pump schemes, wherever feasible, with piped water supply which is more reliable and sustainable in terms of operation.

Steady but slow progress is being made to fill the gap between coverage and usage caused by dwindling water resources by ensuring a minimum quantity of water supply throughout the year. Measures such as rainwater harvesting and groundwater recharge are currently being introduced as an integral part of all rural water supply schemes. These operations have to be geared up with the aid of the latest technologies so that the results can be expedited.

REFERENCES

Black, Maggie. 2000. “From Hand-pump to Health – the evolution of water and sanitation programmes in Bangladesh, India and Nigeria”. www.unicef.org/publications

Black, Maggie and Rupert Talbot. 2005. *Water: A matter of life and health*. New Delhi: Oxford University Press.

Economic Surveys. 1980-2005. www.indiabudget.nic.in/es1980-85 and www.indiabudget.nic.in/es2004-05.

Kumar, Bhishm and S.M. Seth. 2000. “Isotope Hydrology: Present status and future prospects in India.” Paper presented at the International Conference on Integrated Water Resources Management, organised by National Institute of Hydrology, New Delhi.

Meenakshisundaram. 2003. “Provision of Safe Drinking Water to Help Achieve Nutrition Targets”. In Swaminathan and Medrano (ed.) *Towards Hunger-Free India:Vision to Action*. Chennai: EastWest Books.

Planning Commission. 2002. *India Assessment 2002: Water Supply and Sanitation*. New Delhi: Planning Commission, Government of India.

Rajiv Gandhi National Drinking Water Mission (RGNDWM). Various years. *Annual Reports*.

———. 2004 *Technical Note on School Water Supply, Sanitation and Hygiene Education*. New Delhi: Ministry of Rural Development, Department of Drinking Water Supply, Government of India.

———. 2005. *Background Note on Rural Water Supply and Sanitation*. New Delhi: Ministry of Rural Development, Department of Drinking Water Supply, Government of India.

Shivanna, K., K.Thirumalesh, Noble Jacob, Archana Deodhar, T.B. Joseph, S.V. Navada, Gurshran Singh and Vinod Katti. 2005. “Identification of Recharge Zones to Drying Springs in Gaucher, Uttaranchal, using Isotope Hydrogeochemical Techniques.” Report by Isotope Applications Division, Bhabha Atomic Research Centre. New Delhi.

UNICEF. 1995. *Strategies in Water and Environmental Sanitation*. New York: UNICEF.

_______. 2000. *Learning from Experience: Evaluation of UNICEF’s Water andEnvironmental Sanitation Programme in India, 1966-1998*. New York: Division of Evaluation, Policy, and Planning, UNICEF.

WHO/UNICEF. 2001. *Access to Improved Drinking Water Sources– India***.** *Joint Monitoring Programme for Water Supply and Sanitation Coverage Estimates 1980-2000.* New Delhi.

www.planningcommission.nic.in/data/dataf.html.

www.twadboard.com

www.rural.nic.in/rgndw.htm

9

ENERGY*

9.1 Introduction

Energy is a primary driver of economic growth and welfare. It enables use of technologies and machines to increase productivity. Quality energy provides a means to improve the standard of life of people. India has come a long way since 1947 in building the capability to produce quality energy and to distribute it to rural areas. While power in India is predominantly from conventional sources, generated in thermal, hydro and nuclear plants, the country is also one of the leaders in renewable energy production. In the post-Independence period, power generation as well as consumption across sectors has progressed considerably. India has one of the largest and most complex power grid systems among developing countries. India has domestically developed competence in demand forecasting, power plant design and creation, technical specifications, project management and engineering capabilities. However, despite tremendous advances in energy production, demand for power still outstrips the supply.

There is a wide disparity between rural and urban India with regard to consumption of quality energy. Therefore, provisioning of energy to villages has been an important development strategy of the government. This chapter discusses technological interventions that have helped in augmenting the supply of various sources of energy as well as the progress of energy consumption in rural areas over time. While energy does not lend itself to identification of catalytic technologies, along the lines of other sectors, there are significant technological milestones that have propelled growth. Investment, policy and successful technology absorption have been the primary drivers of supply. In this chapter the major technological interventions in conventional as well as renewable energy are detailed, followed by an analysis of progress in supply and improvement in consumption of power across different sectors in the rural areas.

9.2 Technological Interventions

Growth in power generation in the country can be explained by government policies to expand investment in the sector combined with adoption of prevailing technologies in building power stations. Rural electrification was considered an important infrastructural factor for rural development. The Planning Commission, through the Rural Electrification Corporation (REC), has provided the financial resources for the State Electricity Boards (SEBs) to implement rural electrification as well as to correspondingly increase supply capacity. State governments have also laid down yearly rural supply goals to be met. Creation and extension of the grid, the transmission network and distribution lines that take the power to the villages represent the last mile in the supply side.

* Contributed by Mr. Karuna Krishnaswamy, Research Associate, Institute of Financial Management and Research, Chennai.

Thermal power has always been the most important source of power supply in India. It accounts for more than 70 % of total installed power capacity[1] today in the country. After the creation of the national grid, since electricity flows through the path of least resistance, it can reasonably be presumed that 70 % of rural demand has been met by a similar proportion of thermal power generated. Thermal power has contributed the most to rural areas, with hydro power following to a lesser extent. Technology adoption by domestic research and development (R&D) and by successful absorption from abroad has been a key propellant of growth. The thermal and hydro power sectors can be characterised as having been successful in foreign technology absorption, learning and customisation to local needs. Important technological innovations that have been adopted in thermal, hydro and nuclear plants as well as innovations in renewable energy are discussed below.

9.2.1 Technologies in Thermal Plants[2]

Indian thermal plants are primarily coal based and to a lesser extent gas and diesel based. Indian coal has a relatively high ash content, which makes it a less efficient source of heat while its low sulphur content makes it cause less air pollution. High ash content also necessitates better cleaning and combustion methods to extract the maximum thermal energy. The need to adapt technology to domestic raw materials has induced technological development in thermal power generation in the country. Much of the success in supply augmentation can be attributed to successful technology imports and domestic competency building by Bharat Heavy Electricals Limited (BHEL) in power generation, transmission, transportation and industrial systems. Since BHEL's foreign collaborators did not face high ash content in coal, the development of indigenous coal-combustion technologies was undertaken in the mid-1970s. This has been one of the more successful areas of R&D within BHEL. It has resulted in the development of fluidised bed boilers, the direct ignition of pulverised coals, and hot gas clean-up systems, as well as many other modifications in design. Further, coal water slurrying techniques, which make it possible to transport coal mixed with water through pipelines rather than by rail, have made supply of coal from the mines to the plants more efficient.

BHEL has been effective in absorbing technology to become fairly self-reliant in the basic steps of energy generation, transmission and distribution. Three policies that have helped build domestic competence are: the creation of public sector enterprises that possessed the financial resources for the high investment levels needed for large units, import protection from dumping in order to develop local competence, and the standardisation of large plant unit sizes. Increased self-reliance was made possible by structural changes in the organisation of BHEL, initiated in the mid-1970s, which introduced engineering development centres and a specialised R&D centre. This made it possible to systematically initiate technology development in the company. Competence in the production of boilers, heaters and turbines was established. BHEL not only satisfies domestic demand in terms of fabrication of seamless cold and hot tubes, but also exports to other countries.

Apart from increasing the number of thermal plants, enhancing plant capacity and plant efficiency contributed to increasing power generation. Until the 1970s, the plant sizes did not exceed 100 MW and

---

[1] Installed capacity is an indication of the total power that could potentially be generated from a plant running continually through a given period of time, if there were no losses due to inefficiency.

[2] The review of technologies in thermal plants is based on reports from the Central Electricity Authority (CEA) website, Kolar and Sastri (1999) and UNCTAD (1987).

these did not use the reheat system and were less efficient. The introduction of 200 MW plants in 1977 with the reheat system started to increase overall efficiency. Higher steam parameters were adopted in these units, resulting in better cycle heat rates. Moreover, investment in renovation and modernisation of thermal plants in the 1980s improved the plant load factor (PLF), the primary measure of generation efficiency, and decreased heat wastage. The introduction of 500 MW plants in 1984, whose number has grown to 27 units as of 2006, has been an important step. The largely indigenously manufactured 500 MW units have recorded much better PLF than the other capacity groups. The PLF of 200 to 500 MW plants are significantly higher than the all India average indicating the higher efficiency of these plants. Improved and reliable designs by manufacturers and the adoption and modification of foreign technology to local conditions have been important factors. With the operation of these units, the Indian utilities have improved usage of indigenous coal, stringent water chemistry and other operational and safety considerations associated with higher sized units and steam parameters and cycle configuration. BHEL has also entered into collaborations for manufacture of higher size turbo-generators and boilers using supercritical parameters. Energy audits have also contributed to increasing efficiency although there is scope for improvement in this area.

Further technologies that have been adopted in Indian coal plants are as follows:[3]

1. *Pulverised coal (PC) firing with oxides of nitrogen (NO_x)*: Coal is pulverised to microscopic sizes before combustion in the thermal plant. The heat is transferred to steam, which is subject to high pressure. This process increases combustion efficiency of the power boilers to 99 % and thermal (boiler) efficiency to 80-90 %. Drawbacks include high emission of nitrogen oxides, which needs to be controlled. Emission of sulphur oxides is not a big factor with Indian coal.

2. *Coal beneciation*: This is a process to clean the coal (especially of its ash content) before it is supplied to the thermal plants. Poor coal quality leads to plant damage and low PLF.

3. *Atmospheric fired bed combustion (AFBC)*: AFBC technology consists of a bubbling fluidised bed boiler with limestone particles operating with crushed coal as fuel with fluidising air velocities. This leads to high heat transfer efficiency. With PC fired sub-critical boilers, AFBC plants offer a modest overall plant efficiency of 33-37 % but their benefits include fuel flexibility and better environmental performance. Two small units using AFBC are operating currently.

9.2.2 Technologies in Hydro Power Plants[4]

Improvements and technological innovations in hydroelectric turbines, generators and governing equipment in the past 25 years have produced a new generation of hydro equipment that offers higher efficiency, lower cost and improved reliability. These advances are being applied to new installations as well as existing hydro power plants.

From the 1920s to the 1940s, hydro power primarily provided base load energy, with the turbines operating at 50 to 100 % of their rating. Now, the main purpose of hydro power is to meet the peak load demand and hence the units operate at 80 to 110 % of their ratings. In the past 20 years, very low head

[3] Appendix lists advanced coal technologies and their adoption status in India.

[4] The review of technologies in hydro power is from reports published on the www.cea.nic.in, and Chopra (2004)

power projects have been developed using technological innovations, and with improved control of different water velocities. Thirty years ago, units were shut down for major repairs on a regular basis, which is not the case today with new designs and availability of better materials and finishes given to the runner and underwater components of turbines by improved manufacturing processes. Prior to the 1950s, machines were over-designed to anticipate unknown factors and were designed on conservative methods using outdated knowledge of stresses and loadings. Also, defects in the material could not be detected. Machines built today with improved design and manufacturing techniques last longer than older machines as defects in the material can be detected more easily with radiography and non-destructive techniques. With improved design techniques, higher speed turbines are being employed that reduce the size of the unit, powerhouse width, unit spacing, etc., thereby reducing the costs.

Turbine governors have experienced two significant technological changes since the 1960s. These changes, combined with turbine and generator improvements, have had a major impact on the overall efficiency of hydro plant operations. For approximately 100 years, governors were mechanical devices using centrifugal force produced by mechanical fly-weights to detect speed error in the turbines. In the 1960s, governor technology changed from mechanical to electronic analog equipment. The change resulted in faster detection and control of a turbine's speed, and hence less deviation and errors in overall frequency and load. In the 1970s, digital hydraulic control type governors were developed which allowed more intelligent functions in addition to governing, such as logic-based start-up and monitoring.

The advances in governor technology paved the way for completely computerised, automated plant controls. Since the last decade of the 20th century, the set up of major plants has been entirely based on microcomputers and programmable logic controllers for generator load sharing and turbine optimisation. This has improved water management and reduced overall personnel operating costs. The computer-based programmable controls improve the efficiency of the entire plant operation by maintaining the correct relationships between the machinery and the water flows, as well as quickly diagnosing problems and giving the operating personnel the capability of faster troubleshooting.

Advances have taken place in the field of welding materials and methods in the past 30 years, and as a result all major components subjected to pressure and stresses can be welded today instead of being cast. High-strength steel used in scroll case and wicket gates results in lesser thickness of steel, less obstruction of the water passage, and less energy loss.

The most significant improvement in generator technology for hydro facilities has been the use of Class-F insulating material instead of Class-B material in stator winding. Class-F insulation is thinner than Class-B and it can withstand a higher temperature rise. With the superior insulation, the unit can run at a higher temperature and generate more energy, in addition to being smaller and less costly. The other advancement is in the field of gas-insulated switchgear used in some power stations to decrease maintenance effort as well as to facilitate installation in the limited space available at hydro project sites. Vacuum circuit breakers have replaced air circuit breakers to control arcing, and thus reduce maintenance and initial cost. Protective relays have progressed from electro-mechanical devices to numerical relays that are programmable.

9.2.3 Technologies in Nuclear Power Plants

Nuclear power plants require an advanced level of technology and research and hold a place of pride on the Indian technology shelf. Although currently it represents only 3 % of total power generated, nuclear energy is expected to increase steadily in terms of share of total power in order to achieve national energy security. Most of India's achievement in this sector is the result of indigenous technology development covering the complete nuclear cycle — from uranium exploration and mining through fuel fabrication, to heavy water production, reactor design and construction, to power generation and waste management. Accelerators and research and power reactors are now designed and built indigenously.

Nuclear power has the desirable property of not depleting scarce fossil fuels. Currently uranium is the primary fuel used, although its reserves are modest, whereas there is abundant thorium, which is one of the possible ingredients, available in the country. The currently operational nuclear reactors using uranium adopt the pressurised heavy water reactor (PHWR) technology and its associated fuel cycle facilities, and are in the industrial domain. The next stage is the development of fast breeder reactors (FBR) backed by reprocessing plants and plutonium based fuels. A prototype 40 MWe fast breeder test reactor (FBTR) was set up and it attained criticality in 1985. FBTR has provided us with valuable experience with liquid metal FBR technology and the confidence to embark upon the design and technology development of a 500 MWe prototype fast breeder reactor (PFBR).

The third stage will be based on the thorium-uranium-233 cycle. Uranium-233 is obtained by irradiation of thorium in PHWRs and FBRs. An advanced heavy water reactor (AHWR) is being developed at Bhabha Atomic Research Centre to expedite the transition to thorium-based systems. In addition, it will enable the sustainability of some of the heavy water technologies already acquired. The third stage using thorium will improve efficiency and generation when completed. India's reactor plans have in the past been affected by many delays and poor operating load factors. However, both the construction programme and reactor operations improved considerably in the 1990s — reactor load factors are now at 85 %.

The 14 current reactors of aggregate 2.5 gwe capacity include two small boiling water reactors (BWR) from the USA and two small Canadian PHWRs. The remainder is ten local 200 MWe PHWRs, based on a Canadian design. Also planned are six PHWRs, two with increased capacity of 490 MWe, plus two VVER-1000s from Russia.

The Indian nuclear sector is under the direct control of the Department of Atomic Energy. The Uranium Corporation of India operates underground uranium mines and is developing the extensive thorium resources. These account for about one quarter of the world total and contrast with the poor position in uranium, with only 54,000 tonnes of reasonably assured resources. The Nuclear Fuel Complex at Hyderabad is responsible for uranium refining and conversion and also for fuel fabrication for all the reactors. The Nuclear Power Corporation of India builds, owns and operates the nuclear power plants. The research and development facilities include the Bhabha Atomic Research Centre near Mumbai and the Indira Gandhi Centre for Atomic Research at Kalpakkam, near Chennai.

9.2.4 Renewable Energy Technologies

The rationale for developing renewable energy is to:

1. Enhance the substitution of depletable primary fuels and minimise dependence on largely imported fossil fuels
2. Augment energy supply and provide power to remote locations where conventional power supply is not feasible
3. Enhance the diversity and security of energy supplies through the optimum utilisation of indigenous resources
4. Support local and global environmental protection
5. Promote private-sector participation and competitiveness
6. Facilitate enhanced local participation, specially of women and NGOs; and generate employment, particularly in rural areas
7. Improve the quality of energy in rural areas to improve quality of life and livelihood

India is one of the leaders in renewable energy production. There has been a high degree of indigenous innovation in renewable energy technology. Renewable energy uses readily available biomass, and non-depletable sources like wind, sunlight and waste. Renewable energy technology is characterised by the transfer to the end-user, of ownership of production, servicing and operation of the installation, in addition to consumption. Conventional power on the other hand is produced centrally, transmitted to distant locations and then distributed to an end-user who is purely a consumer. Renewable energy is largely targeted at rural India. The Indian Renewable Energy Development Agency Ltd. (IREDA) was established in 1987 as a public sector enterprise for the promotion, development and financing of new and renewable energy technologies.

The Ministry of Non-Conventional Energy Sources (MNES) is implementing programmes on solar energy, wind energy, chemical sources of energy, hydrogen energy, geothermal energy, ocean energy and biofuels for surface transportation (battery-operated vehicles). As part of these programmes, a number of R&D and demonstration projects have been taken up through research and educational institutions, universities, national laboratories and the industry.

The technologies developed in renewable energy are described below:

- The National Biogas Management Programme (NBMP) was introduced in 1981–82. Biogas plants, indigenously developed, present a good alternative to firewood and LPG. Biogas is an efficient fuel and the leftover digested slurry can be used as enriched manure for agriculture and pisciculture.
- The National Programme on Chulhas was instituted in 1983. Firewood as a cooking fuel represents about 40 % of the total energy consumption in the country. Chulhas improve efficiency by about 50 % and reduce indoor pollution.
- The Biomass Gasifier Programme was started in 1986. This technology converts suitable biomass such as firewood into gaseous form to generate power for irrigation.

- Bio-diesel plants (*Jatropha curcas* and *Karanja*) are seen as viable alternatives to conventional fossil-based fuels for compression ignition engines and R&D efforts are on in this direction.
- The Wind Energy Generation Programme was initiated in 1985-86 through demonstration projects and India ranks 5th in the world in installed capacity. While wind energy currently makes up about only 1.4 % of total capacity, it promises to be a big factor in the future.
- Co-generation was introduced in 1993 and is the process whereby thermal energy that is produced for use in a manufacturing plant (like fertiliser or sugar) is further converted into electrical energy. The industry uses the power produced and the excess is sold to the State Electricity Boards.
- The National Programme on Energy Recovery from urban, municipal and industrial waste was launched during 1995–96 to convert waste into a potential 2000 MW of energy.
- Fuel cells produce electricity from an electrochemical reaction between hydrogen, oxygen or air and the use of fuel cells has been demonstrated for stationary and portable power generation.
- The Alternative Fuel for Surface Transportation Programme focuses on the development and deployment of battery-operated vehicles, which are environmentally benign, noise-free and consume no oil. CNG-operated vehicles that are environment friendly are already in operation in Delhi.
- R&D and demonstration programmes have been undertaken on geothermal energy.
- Small hydro power (SHP), up to 25 MW capacity, has been identified as one of the sources for electrification of remote villages.
- Solar energy has been identified as a reliable source of power and heat. Solar energy conversion systems are used for decentralised applications. Solar water heating systems, solar cookers and solar air heating technologies have been commercialised in India. Further, power generated from solar photovoltaic (PV) cells is one of the most mature sources of renewable energy.

Table 9.1 shows India's rank in the world in terms of installed capacities of various renewable energy sources. The country's biggest successes are in biogas plants, efficient chulhas, and solar cookers.

Table 9.1: India's Standing in Renewable Energy Sources

Type	Rank in world
Biogas plants	2
Wind	4
Efficient chulhas	2
Solar cookers	1
Photo-voltaic water pumps	3
Micro / mini hydel	10

Source: MNES (Annual Report 2002)

9.3 Progress in the Energy Sector

Progress in the energy sector may be seen in terms of improvement in power generation as well as access to power across different sectors over the past five decades.

9.3.1 Power Supply in Conventional Energy Sources

Electricity is the preferred form of commercial energy. It lends itself to easy and instantaneous transmission and distribution from a geographically remote location to an end-user who can tap it at a desired rate, safely and economically. Power is generated in power plants, goes through a substation and is carried to a transformer in the proximity of the user through transmission lines (the power grid), from where it is taken to the end- user through distribution lines.

Conventional power is produced from thermal, hydro and nuclear plants. Installed plant capacity has increased rapidly over the last five decades in India. In 1950–51, the total installed capacity was 2.3 thousand MW and over the next fifty years it has increased at an annual compound growth rate of 8.17 %. By 2000–01 the installed capacity was 118 thousand MW. The biggest increase in capacity has been since 1980–81 with an addition of about 41,000 MW in the 1980s and 43,000 MW in the 1990s (**Table 9.2**).

Table 9.2: Progress of Installed Plant Capacity of Electricity Supply, India

(thousand MW)

Year	Utilities				Non-utilities	Total
	Thermal	Hydro	Nuclear	Total		
1950-51	1.1	0.6	--	1.7	0.6	2.3
1960-61	2.7	1.9	--	4.6	1.0	5.6
1970-71	7.9	6.4	0.4	14.7	1.6	16.3
1980-81	17.6	11.8	0.9	30.2	3.1	33.3
1990-91	45.8	18.8	1.5	66.1	8.6	74.7
2000-01	73.6	25.1	2.9	101.6	16.2	117.8

Note: Thermal includes wind; Non-utilities or captive power generation: power generated by industries typically manufacturing for personal consumption and may or may not be connected to the power grid. Utilities: generation by dedicated power stations.

Source: Economic Survey (2004-05)

From **Table 9.2** it is clear that thermal plants followed by hydro plants account for the bulk of installed plant capacity. By 2001, thermal accounted for 63 %, hydro 21 % and nuclear less than 3 % of the overall capacity in the country.

Table 9.3: Progress in Power Generation in India

(billion kwh)

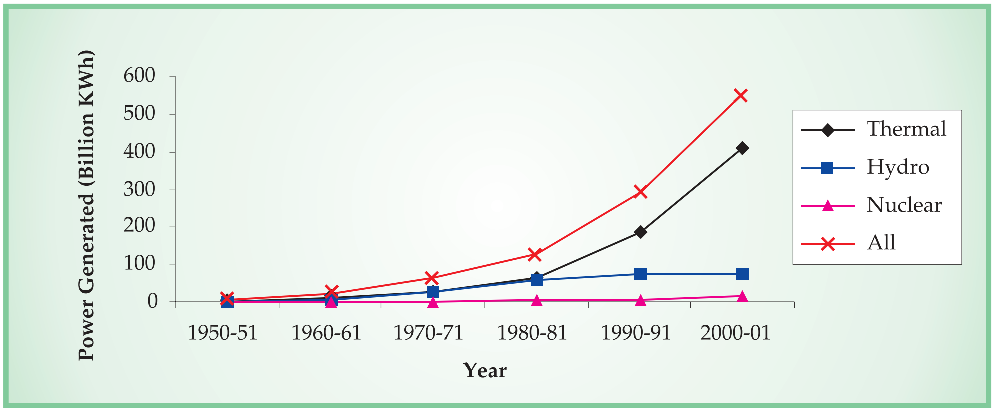
Year	Utilities				Non-utilities	Total	Power generated per capita (kwh)
	Thermal	Hydro	Nuclear	Total			
1950-51	2.6	2.5	--	5.1	1.5	6.6	18.28
1960-61	9.1	7.8	--	16.9	3.2	20.1	46.31
1970-71	28.2	25.2	2.4	55.8	5.4	61.2	113.12
1980-81	61.3	56.5	3.0	120.8	8.4	129.2	190.28
1990-91	186.5	71.7	6.1	264.3	25.1	289.4	344.93
2000-01	408.1	74.5	16.9	499.5	55.0	554.5	544.16

Note: Thermal includes wind.

Source: Economic Survey (2004-05)

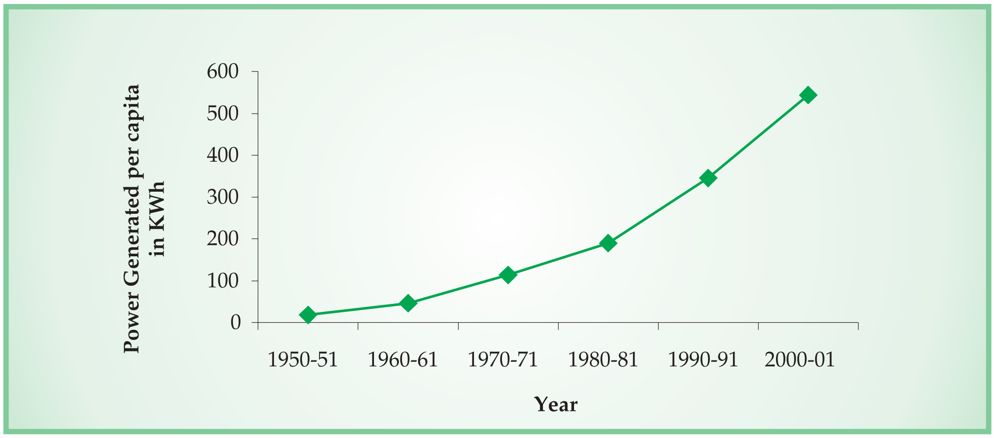
The total power generated by all the plants combined has also progressed significantly over the last fifty years. From 6.6 billion kwh in 1950–51, power generation increased at the rate of 9.2 % per annum over the five decades and was 554.5 billion kwh by 2000–01. The ratio of power generated to installed capacity rose till 1981, stayed flat in the 1980s and rose dramatically in the 1990s. A simple interpretation of this figure is the amount of power one unit of installed capacity is actually generating and is related to increased operation time and efficiency of the plants. Of the overall power generated in 2000–01, 74 % was from thermal plants, 13 % from hydro plants and 3 % from nuclear plants. Thermal power accounted for less than 50 % of total power generated in the country up to 1970–71. It has increased steadily and by 2000–01 it contributes about 75 % of total power generated in the country. There has been a significant improvement in power generated per capita, from 18 kwh per annum to 544 kwh per annum over the last five decades.

Figure 9.1: Power Generated in India



Source: Table 9.3

Figure 9.2: Power Generated Per Capita, India



Source: Table 9.3

Efficiency of thermal power generation has also improved over the years. Average plant load factor (PLF) of thermal plants is considered a measure of efficiency of thermal plants. An analysis of data from the Economic Survey and The Energy Research Institute indicate a rise in PLF of thermal plants from 44.3 % in 1979–80 to over 74.8 % in 2004–05 (Nagaraj 2006). PLF in thermal plants was 27 % in 1950–51 (Dadhich undated).

The disadvantage of electricity is that it cannot be stored easily. The creation and strengthening of regional power grids has been an important milestone. The grid strengthening facilitates the transmission from a surplus plant to a distant consumer and handles higher plant capacities. India has one of the most complex grids in the world especially since it has to reach geographically unfriendly terrain in remote rural areas. Along with improvement in power generation, there has also been a significant growth in transmission and distribution lines from less than 40,000 circuit km to more than 5.7 lakh circuit km (**Table 9.4**). This has directly contributed to the increase in rural consumption of power over the years. Competence in building transformers and transmission lines of higher voltage capacities has improved transmission capacity. However, power generated is not equal to the power consumed in the country, largely due to losses in transmission and distribution. This is an area of concern as losses have steadily increased over the years from 14 % in 1961–62 to 33 % in 2000–01.

Table 9.4: Growth in Transmission & Distribution Lines, India

Year	T & D Lines (circuit km)
1951	39,064
1961	1,57,887
1971	11,17,163
1981	25,22,461
1991	45,33,414
1999	57,10,396

Source: CEA (various years)

9.3.1.1 Environmental Impact

Needless to say, power generation from the above sources comes at a cost in the form of environmental damage, with air pollution being the most common. In general, thermal plants cause air pollution through emission of toxic gases, particulate matter, fly ash and bottom ash. Carbon- and nitrogen-based emissions cause the greenhouse effect, which leads to increase in the surface temperature of the earth, while sulphur and nitrogen cause acid rain. Most of the emissions cause damage to buildings, to human health and to flora and fauna. Indian coal has low sulphur content and hence SO_2 emission is not a concern. However, its high ash content leads to emission of particulate matter, some of which is respirable and pose hazards to human health, and suspended emissions, which cause environmental damage.

The Central Pollution Control Board (CPCB) sets standards for acceptable emissions from thermal plants as well as for ambient air quality. The existing emission standard for particulate matter (ESP) in India is more tolerant at 150 mg/m^3, compared to the proposed World Bank standard of 50 mg/m^3.

9.3.1.2 Oil and Natural Gas

Crude oil is a hydrocarbon that is processed into a readily usable efficient form in refineries. Its most important derivatives are petrol, diesel, kerosene and naphtha. Natural gas is a combustible fuel which is used for generating power, as an industrial fuel, in fertiliser and petrochemical plants, for LPG and more recently as CNG. While India's imports of crude oil has always been much higher than domestic production, the difference between domestic production and imports grew very wide over the 1990s with the government pursuing policies of liberalisation.

Table 9.5: Domestic Production and Net Imports of Crude Oil and Petroleum Products

(million tonnes)

Year	Crude Oil		Petroleum Products	
	Domestic production	Net imports	Domestic production	Net imports
1960-61	0.5	6.0	5.7	—
1970-71	6.8	11.7	17.1	0.8
1980-81	10.5	16.2	24.1	7.3
1990-91	33.0	20.7	48.6	6.0
2000-01	32.4	74.1	95.6	0.9

Note: Petroleum products include naphtha, kerosene, high speed diesel oil, and fuel oils.

Source: Economic Survey (2004-05)

9.3.2 Rural Energy Consumption

9.3.2.1 Electric Power

Rural Electrification (RE) is an important infrastructural factor for increasing agricultural productivity, creating rural industries, generating employment, increasing the quality of life of the rural population, and lowering rural-urban migration. The Rural Electrification Programme, which was started in 1948 soon after Independence, gained momentum with the creation of the Rural Electrification Corporation (REC) in 1969. REC's mandate was to provide finance to State Electricity Boards (SEBs) for rural electrification projects using conventional grid based power. It has been a planned process, based on projected economic growth, demand forecasts and governmental development objectives. The Planning Commission has increased investment over the years to progressively extend the reach of transmission and distribution lines to villages, with emphasis in recent years on poorer households and hamlets and remote areas. Sen and Dawar (1977, as cited in NCAER 1986) had estimated the cost to electrify a representative village to be Rs.80,000 and Rs.1,00,000 for one in hilly, desert or tribal areas, at 1977 prices. The initial emphasis on rural electrification was based on the premise: Create the supply and the demand will come.

Significant progress in rural electrification has been achieved over the past four decades (**Table 9.6**). From 1961 to 2001, electrification of villages grew at an annual compound growth rate of 8.23 % with the majority of the villages being electrified in the 1970s and '80s, though there was a slowing down of progress in the 1990s. Originally a village was essentially deemed electrified if a transmission line reached it and SEBs reported that an impressive 87 % of all villages had been electrified, with many States reporting even 100% villages electrified in the year 2001. This was indeed an accomplishment, considering the unfriendly terrain and dispersed locations of villages in many States. However, as of 2003, 70,135 villages were non-electrified out of a total of 5,87,258, without counting de-electrified villages (Rajya Sabha Unstarred Question No. 3515, 23.4.2003). It is clear that the large percentage of villages reported to be electrified was only because of the definition that was followed previously. The new definition of village electrification requires that:

- Basic infrastructure such as distribution transformers and distribution lines be provided in inhabited localities, including dalit colonies / hamlets
- Electricity is provided to public places like schools, panchayat offices, health centres, dispensaries, community centres, etc.
- The number of households electrified should be at least 10 % of the total number of households in the village

If this new definition is applied and if de-electrified villages are also included, the number of non-electrified villages is expected to be at least double, thereby reducing village electrification to little less than 70 % as of 2004 (Planning Commission 2005).

Table 9.6: Growth of Electrification in Rural India

Year	Number of villages electrified	Percentage of villages electrified	Percentage of rural households electrified
1961	21,474	3.83	0.58*
1971	1,04,939	18.51	3.75*
1981	2,72,287	47.30	14.69
1991	4,81,124	83.08	30.54
2001	5,08,431	86.58	43.52

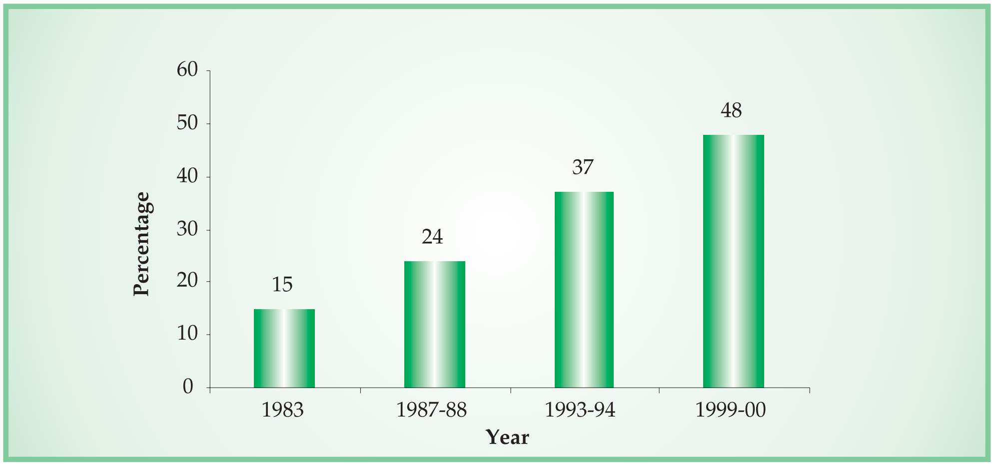
Note: 1981 data does not include Assam and 1991 does not include Jammu & Kashmir

* Date not available: estimated by linearly regressing rural households electrified on villages electrified to household electrified ratio.

Source: CEA (various years); www.censusindia.net; CMIE (1993)

According to census figures, even by 2001, only 44 % of households had access to electricity. However, the National Sample Survey estimates for 1999–2000 indicate a slightly higher percentage of rural households (48 %) having access to electricity for lighting. **Figure 9.3** indicates the considerable progress in household electrification over the last two decades. There is a wide disparity between households in rural and urban areas with regard to access to electricity. In 1999–2000, while 89 % of households in urban India had access to electricity, the corresponding figure for rural India was 48 %. Within rural areas, usage of electricity varies across social classes as is evident from **Table 9.7**.

Figure 9.3: Percentage of Rural Households Using Electricity for Lighting



Source: NSSO (1993-94 and 1999-2000)

Table 9.7: Households Using Electricity for Lighting Rural India, 1999-2000

Social Group	Percentage of estimated households in rural India	Percentage of all rural households using electricity for lighting	Percentage of households using electricity for lighting within each social group
Scheduled Tribe	10.88	8.40	37.40
Scheduled Caste	21.24	17.25	39.30
Other Backward Class	37.10	37.40	48.80
Others	30.67	36.94	58.30
All	100.00	100.00	48.40

Source: NSSO (1999-2000)

Table 9.7 clearly brings out the correspondence between access to electricity by households and the social groups to which they belong. Among less privileged classes, electricity is used by a lower percentage of households and vice versa. Households belonging to the category 'others' (that is, all non-Scheduled Tribes, non-Scheduled Castes, non-OBCs) comprise about 31 % in rural India, but account for a much larger percentage of households using electricity for lighting. Scheduled Castes settlements have a smaller share of distribution lines, which is reflected in their communities having fewer households electrified compared to the rural average. According to the census data, in 2001, 30 % of Scheduled Caste households reported access to electricity while among all rural households it is 43 %. To address this, many States have independent schemes providing free connections for the poor and Scheduled Castes and Scheduled Tribes households. The *Katir Jyoti* Programme (KJP) was commenced by REC in 1988 to provide single point light connections to poor rural households, with special quotas for Scheduled Castes and Adivasi families. By 2001, 5 lakh households in rural India had benefited by this scheme.

National Sample Surveys reveal that household electricity connections are affordable largely only by the richer households. In 1999–2000, rural households belonging to the category of monthly per capita expenditure of above Rs. 525, that is, the top 20 % of all households, accounted for 50 % of electricity connections for lighting (NSS 1999–2000). Per capita power consumption in the country as a whole was 37.9 kwh in 1960–61 and it increased tenfold in four decades and was 373 kwh in 2002–03 (Central Electricity Authority 2002–03). Data on per capita power consumption in rural areas is not available and is only estimated based on occasional surveys. **Table 9.8** shows estimates by The Energy Research Institute (TERI) and Fuel Policy Commission indicating the progress in villages.

Table 9.8: Estimates of Rural Power Consumption, India

(in kwh)

Year	1973-74	1978-79	1999-2000
Rural per capita power consumption	2.2	4.9	76.2

Source: TERI (2001-02)

While rural electrification had made rapid strides in the 1960s, even by 1973–74 per capita power consumption in rural areas was only at an abysmally low level of 2.2 kwh. Remarkable progress has been achieved over the 1980s and '90s and by 1999–2000, the per capita rural power consumption was of the order of 76.2 kwh, though still much lower than in urban areas.

9.3.2.2 Domestic Fuels

About 95 % of rural households depend primarily upon biomass fuels, such as firewood, cow dung and crop residues, for meeting their cooking and heating requirements. These are inefficient sources of energy, burnt in an inefficient manner in traditional stoves. Biomass fuel is collected at the cost of significant time and effort that could be diverted to more productive activities. The indoor pollution causes health problems for women. The present level of consumption of firewood is considered unsustainable as demand outstrips supply, leading to loss of forest cover. The burning of animal waste and agricultural residues deprives the soils of much needed organic matter, adversely affecting soil health and agricultural productivity.

Urban households use preferred fuels like LPG and kerosene and more recently, piped natural gas. Penetration of these in rural areas has been quite minimal (**Table 9.9**). Reasons commonly cited are the cost of an LPG-based stove, the initial cost of an LPG connection, ongoing refill costs, access and timely availability of refills and mindset of users. To overcome such problems, the government has launched programmes to provide subsidised LPG connections and to increase availability of refills in villages. Public distribution systems have been launched through subsidies and additional outlets to increase the use of kerosene for cooking and lighting. Innovative LPG distribution schemes that subsidise the initial connection cost but not ongoing refills and oven costs have been introduced to increase adoption of LPG.

Table 9.9: Percentage of Households Using Modern Cooking Fuels, India

Area	1991	2001
Rural	3.15	7.89
Urban	51.95	67.81
Total	**15.90**	**24.65**

Note: Modern fuels refer to kerosene, LPG, biogas, or electricity.

Source: www.censusindia.net

Table 9.9 clearly shows the abysmally low level of penetration of modern fuels in rural households. The urban rural disparity is not only huge, it has also widened over the 1990s. According to the National Sample Survey, 1.9 % of rural households in 1993–94 and 5.4 % in 1999–2000 use LPG for cooking purposes. **Table 9.10** also brings out the sharp differences across social classes with regard to use of LPG. Nearly two-thirds of all LPG connections are with households that belong to the category of 'others'.

Table 9.10: Rural Households Using LPG for Cooking, 1999-2000

Social Group	Percentage of estimated households in rural India	Percentage of all rural households using LPG for cooking	Percentage of households using LPG for cooking within each social group
Scheduled Tribe	10.88	2.62	1.30
Scheduled Caste	21.24	6.29	1.60
Other Backward Class	37.10	28.13	4.10
Others	30.67	63.01	11.10
All	100.00	100.00	5.40

Source: NSSO (1999-2000)

9.3.2.3 Renewable Energy Sources

To the extent that India imports over 70 % of her crude oil needs and that demand outstrips supply, efforts are being made to achieve fuel security though renewable fuels. The current rate of use of firewood is unsustainable as it increases the rate of loss of forest cover and demand exceeds supply. Biogas penetration has been low, with less than 2 % of rural households, that is, about 3 million rural households, reporting usage in 2001. 16.45 lakh efficient chulhas had been installed as of 2000–01, and a review by NCAER revealed that only 57 % of all the chulhas installed were still working and in use. Despite the tremendous benefits, effective adoption has been slow. As with other renewable sources, getting people to switch permanently to gobar gas has been difficult to achieve. Apart from set-up costs, there is the additional burden to service the biogas plants on a daily basis, which further dissuades usage despite the poor quality of biomass. Renewable power has gathered steam since the 1990s. There has been a small but growing impact. As of 2002, a total of 3612 villages have been electrified through renewable power sources (MNES Annual Report 2003). As indicated in **Table 9.11**, in terms of installed capacity this represents only 3.37 % of total installed capacity from all sources, but this number is expected to grow in the future.

Table 9.11: Installed Capacity in Renewable Power Sources, India, 2003

Total	Wind power (MW)	SHP (MW)	Biomass power (MW)	Biomass gasifier (MW)	Energy from wastes (MW)	Solar photovoltaic power (MWp)	Aerogenerator / hybrid system (MW)
3944.24	1869.5	1509	483.93	53.37	25.73	2.490	0.21909

Note: MWp: Mega Watt Peak
SHP: Small Hydro Power
Source: Lok Sabha Starred Question No. 276, dated 07.08.2003 from www.indiastat.com

Table 9.12: New and Renewable Sources of Non-Conventional Energy, India, 2004

Sources	Potential	Achievement
Biogas	120 lakh	36.50 lakh
Improved Chulhas	1,200 lakh	339 lakh
Wind	45,000 MW	2,483 MW
Small Hydro	15,000 MW	1,603 MW
Biomass Power / Cogeneration	19,500 MW	613 MW
Biomass Gasifiers	-	58 MW
Solar PV	20 MW / sq. km	151 MWp*
Waste-to-Energy	1,700 MW	41.50 MWe
Solar Water Heating	1,400 lakh sq.m collector area	800 lakh sq.m collector area

Note: *Of this 75 MW_p solar PV products have been exported; MWe = Mega Watt (Electric)
Source: MNES (Annual Report 2003-2004)

From **Table 9.12** it is clear that what has been achieved is only a portion of the estimated potential and there is much scope for progress in almost every form of non-conventional energy: while more than 3 million biogas plants have been installed, this is just one-third of the estimated potential and similar is the case with improved chulhas and other sources of energy. It is interesting that achievement with regard to solar PV products in the country is greater than the potential and exports are also taking place.

9.3.3 Power in Agriculture

Farm work traditionally employs a combination of draught animal energy, mechanical energy, and more recently, electric power. Farmers have moved away from less efficient and more cumbersome sources of animal and mechanical energy (non-powered tools) to electricity-powered implements. Over time there has been a steady increase in the share of power in the total energy used in farms, predominantly for pump-set irrigation. Power has led to significant growth in agricultural innovations. The availability of subsidised power has been one of the catalysts of improved agricultural yield. This has enabled farmers to discontinue the use of diesel pump-sets that are more expensive, unusable for deep tubewell irrigation, and are more difficult to operate than electric pump-sets. Pump-set electrification has enabled farmers to undertake double and triple cropping and invest in more water-intensive, higher-value crops.

Table 9.13: Different Sources of Energy in Farms, India

Year	Total power kw/ha of irrigated land	Annual compound growth rate of power consumption per ha. of irrigated land	Farm power classified by source (in percentage)		
			Animate	Mechanical	Electric
1951	0.25 (100)	-	97.4	2.1	0.5
1961	0.31 (124)	2.17	94.9	3.7	1.4
1971	0.36 (144)	1.51	79.2	16.3	4.5
1981	0.63 (252)	5.76	48.2	32.3	19.5
1991	0.92 (368)	3.86	34.5	34.7	30.8
1999	1.25 (500)	3.11	21.0	44.2	34.8

Source: Srivastava (2000, cited in Chopra 2004)

From **Table 9.13** it is seen that power consumption per unit area of irrigated land had increased five times over five decades. The rapid increase over the 1970s had been sustained in the following decade, while there was a marginal decline over the 1990s. The share of animate power has declined drastically over time and there has been a corresponding increase in the share of mechanical and electric power, particularly since 1981. This is largely related to rapid mechanisation of agriculture over the years. Use of tractors, power tillers, combine harvesters, pump-sets and other power-operated machines has grown. In 1971–72, there were 1 lakh tractors in the country and over three decades this increased 25 times and by 2000–01 there were 25 lakh tractors. Over the same period, the number of power tillers increased 7 times from 16,000 to more than one lakh (ICAR 2004).

Table 9.14 shows that the agriculture sector now uses one-fourth of the total power consumed in the country. Power consumption for agriculture increased 10 times over the 1960s and continued to increase rapidly up to 1990–91, and the pace of increase declined during the 1990s. This is also reflected in the consumption of power per well-irrigated area over time. 10 hectares of well-irrigated area consumed less than one kwh of power in 1960–61 and this is close to 25 kwh by 2000–01.

Table 9.14: Power Usage in Indian Agriculture

Year	Percentage share of total power to agriculture	Total power consumption in agriculture [Million kwh]	Power consumption per 10 ha. of well-irrigated land
1950-51	3.9	--	--
1960-61	6.0	410	0.56
1970-71	10.2	4,470	3.76
1980-81	17.6	14,489	8.19
1990-91	26.4	50,321	20.38
2000-01	26.8	84,729	24.81

Note: Third column calculated with data on total land irrigated by wells.
Source: CEA (2002-03); Economic Survey (2004-05)

The focus of the Rural Electrification Corporation has been on pump-set electrification since the drought in the 1960s. Increase in village electrification and subsequent construction of distribution lines to farm areas have contributed to the rise in pump-sets electrified. Though electric pump-sets have increased rapidly over time, diesel pump-sets still account for one-third of all pump-sets. **Table 9.15** clearly shows the rapid mechanisation of agriculture that has occurred over the last three decades: electric pump-sets and power tillers have increased sevenfold while tractors have increased twenty-fold.

Table 9.15: Progress in Farm Mechanisation, India

Year	Number of diesel pump-sets	Number of electrified pump-sets	Number of tractors	Number of power tillers
1971	15,57,000 (100)	16,29,423 (100)	1,19,390 (100)	16,418 (100)
1981	28,10,000 (180)	43,30,453 (266)	5,13,380 (430)	32,400 (197)
1991	48,50,000 (311)	89,09,110 (547)	12,43,600 (1,041)	60,325 (367)
2001	52,00,000 (334)	1,28,30,347(787)	25,99,720 (2,177)	1,22,488 (746)

Note: Diesel pump-set data for the years 1971 and 2001 refer to the years 1972 and 1993 respectively; Data for year 2001 w. r. to tractors and power tillers are provisional; Figures in brackets give the index w. r. to 1971.
Source: CMIE (1996); www.indiastat.com

9.3.4 Power in Rural Enterprises

It is acknowledged by experts that provisioning of power for rural industries is a much neglected area. The potential uses are considerable and include agro-processing, poultry farms, refrigeration of milk, fish farms, cottage industries, manufacture and use of small electric appliances, and hospitals. Lack of comprehensive studies and availability of data makes it difficult to accurately measure the impact of electrification on rural industries. An NCAER study in 1981 reveals that only 7 % of rural electricity was used by industries (NCAER 1986). The current quality of rural power supply does not encourage the growth of industries. Economic literature is unclear on whether economic growth will drive demand or the availability of power infrastructure will drive growth. However, there is broad consensus that village electrification is not an end by itself but should be accompanied by availability of complementary inputs like education, credit, and an entrepreneurial atmosphere for successful rural development.

Extent of electrification in rural industries is quite minimal and the absence of consistent survey data makes it difficult to track progress over time. Rural industry electrification started low and according to the Census of Industrial Establishments, in 1960 just about 1% of industries in rural India used electricity and this rose to 5 % by 1970 (Census of Industrial Establishments, 1960 and 1970, as cited in World Bank 1979). The National Sample Survey in 1994–95 shows that about 8 % of all unorganised enterprises in rural India uses electricity while the corresponding figure for urban areas is about 30 % (NSSO 1994–95). Data for the decades after the 1970s are available from the Economic Census Surveys, which give the complete count of all entrepreneurial units located in the country. From these surveys we have data for three time points: 1980, 1990 and 1998. These surveys count the total number of enterprises, and indicate the ones that report having premises and whether they use power or fuel (for 1980 and 1990) and only power (for 1998). From **Table 9.16** it is evident that the percentage of enterprises using power / fuel in rural areas had not registered a rapid increase over the 1980s and '90s. While 15.5 % of all rural enterprises were using power in 1980 this had increased only by 3 percentage points over nearly two decades. It is important to note that data for 1998 reflected enterprises using power only, which partly explains the slower growth. However, the progress in establishments has been relatively better compared to own account enterprises.

Table 9.16: Rural Enterprises Using Power or Fuel in India

Year	Number of OAEs using power or fuel	Number of establishments using power or fuel	Total number of OAEs	Total number of establishments	Percentage of OAEs using power or fuel	Percentage of establishments using power or fuel	Percentage of all rural enterprises using power or fuel
1980	12,67,117	4,61,756	86,45,689	24,95,689	14.66	18.50	15.52
1990	18,03,854	7,59,038	1,13,17,351	34,04,896	15.94	22.29	17.41
1998	22,66,832	10,27,349	1,36,00,737	41,06,738	16.67	25.02	18.60

Note: 1. According to the Economic Survey, an enterprise is an undertaking engaged in production and / or distribution of goods and / or services not for the sole purpose of own consumption. An enterprise normally run by members of the household without hiring any worker on a fairly regular basis is an own-account enterprise (OAE). An enterprise run by employing at least one hired worker on a fairly regular basis is an establishment.

2. The Economic Census Survey has categorised enterprises by use of power or fuel till 1990 and only power in 1998. Different sources of power / fuel considered are electricity, coal / soft coke, petrol / diesel, gas, firewood, kerosene, animal power, non-conventional energy and others such as atomic power, etc.

Source: Economic Census (1980, 1990, and 1998)

9.4 Index of Power Diffusion

The power diffusion index for the energy sector is designed to reflect penetration and usage of high quality energy in rural India. The basic indicators used in computing the index are:

1. *Villages electrified*: This is the percentage of villages that are deemed electrified based on the availability of a transmission line running to the village. This also represents the degree of reach of the transmission grid as well as public amenities that might be provided, such as street lighting.
2. *Households electrified*: This indicator reflects the progress in terms of percentage of households that report use of electricity.
3. *Rural enterprises using power or fuel*: This data indicates the percentage of rural enterprises that use power or fuel for purposes apart from heating and lighting. It does not say anything about the need, availability or affordability of energy for rural enterprises.

4. *Pump-set electrification*: This is revealed by the percentage of electrified pump-sets used in irrigation out of the total potential for pump-set electrification as determined by the Planning Commission.

Total kwh power consumption in agriculture is not selected as an indicator to reflect diffusion of power in rural areas because it is acknowledged that these figures are inflated to include transmission and distribution losses and are not reliable. Domestic fuel has not been selected as an indicator given that penetration of non-firewood sources such as kerosene, biogas, LPG or electricity among rural households has not been very significant. Renewable fuel is also not chosen as data available is only on installation and not on ongoing consumption, which may be significantly different. While rural consumption of transportation fuel accounts for a significant fraction of all-India consumption, this data is hard to collect reliably.

Diffusion of power in rural India is seen in terms of access to quality energy by households, enterprises and agriculture over the last two decades. With regard to agriculture, the number of pump-sets electrified is taken to reflect the level of diffusion. To harmonise this indicator with the remaining three indicators which are expressed as percentages (households electrified, villages electrified, enterprises using power) the number of pump-sets electrified is divided by the total potential number of pump-sets in the country that have the potential for electrification.[5] This represents the percentage of total potential that has been electrified thus far. A simple average of the four indicators forms the power diffusion index, assigning equal importance to diffusion in the four sectors.

Table 9.17: Power Diffusion Index across Different Sectors in Rural India, 1981-2001

Year	Percentage of villages electrified	Percentage of rural households electrified	Percentage of rural enterprises using power or fuel*	Percentage of pump-sets electrified out of total potential	Power Diffusion Index
1981	47.30	14.69	15.52	22.10	24.90
1991	83.08	30.54	17.41	45.46	44.12
2001	86.58	43.52	18.60	65.48	65.19

Note: 1. *This column's values are for 1980, 1990 and 1998 respectively.

2. Percentage of pump-sets electrified is calculated by dividing pump-sets electrified by potential number of pump-sets for electrification.

Source: Table 9.6 and 9.16

Table 9.17 indicates that the bulk of growth with regard to village electrification occurred in the 1980s. The slower growth from 1991 to 2001 can be explained due to de-electrification and by the fact that some of the non-electrified ones are hard-to-reach villages that might be better served by renewable sources. The percentage of enterprises using power or fuel has remained practically stagnant since the 1980s. Household electrification has grown at a constant pace over the 1980s and '90s. It should be noted that the total number of villages, enterprises and households vary from year to year. Pump-set electrification, due to a targeted effort by the government and through tariff subsidies, has registered the highest growth of about 20 percentage points addition out of the total 1981 potential, per decade. The power diffusion index moves in tandem with agriculture from 1981 to 2001.[6]

[5] According to an estimate made by the Planning Commission, the potential number of pump-sets is 19,59,4000 (Planning Commission 2002).

[6] This result is expected, considering that experts acknowledge that the bulk of rural power goes to agriculture.

An index for agriculture is computed using the growth of power-operated machinery in agriculture. On the basis of data on the number of pump-sets, tractors and power tillers (as in **Table 9.15**) and area under cultivation (net sown area), the number of machinery per unit area of cultivation is calculated. This reflects the growth of mechanisation or modernisation of agriculture. From **Table 9.18**, it is seen that the use of machinery in agriculture increased rapidly over the last few decades and the overall index has increased tenfold from 1971 to 2001.

Table 9.18: Index of Farm Mechanisation, India

Year	No. of diesel pump-sets per 100 ha of NSA	No. of electrified pump-sets per 100 ha of NSA	No. of tractors per 100 ha of NSA	No. of power tillers per 100 ha of NSA	Index of Growth				Index of farm mechan-isation
					Diesel pump-sets	Electrified pump-sets	Tractors	Tillers	
1971	1.11	1.16	0.09	0.01	100	100	100	100	100
1981	2.01	3.09	0.37	0.02	181	267	407	231	272
1991	3.39	6.23	0.87	0.04	306	537	966	422	558
2001	3.69	9.10	1.84	0.09	332	784	2,048	869	1,008

Note: NSA = net sown area

Source: Table 9.15; www.indiastat.com

9.5 Concluding Observations

Power generation has risen impressively in the past 50 years in India. This has been a consequence of planned investment, successful technology absorption from abroad, indigenous capacity building, and modification of technology to suit local conditions. This growth in power generation has been led by growth in coal-based thermal power. Apart from additional power stations, this has been made possible due to higher installed capacity of thermal power plants, in particular 500 MW power plants that were introduced in the 1980s. This higher installed capacity has led to higher power generation through gains in efficiency because of improved plant load factor. Domestic R&D, successful technology absorption from abroad and competency building by BHEL in power generation, transmission, transportation and industrial systems have spurred growth. One of BHEL's successful areas has been the development of fluidised bed boilers, the direct ignition of pulverised coals, and hot gas clean-up systems, as well as many other modifications in designs to accommodate Indian coal which has high ash content. On the policy side, key elements have included the creation of public sector enterprises with the financial resources needed for large units, import protection from dumping in order to develop local competence, and the standardisation of large plant unit sizes. Moving forward, further investment in renovation and modernisation of power plants and repowering technologies, adoption of clean coal utilisation technologies such as integrated gas combined cycle (IGCC), AFBC, CFBC and advanced technologies like supercritical boiler technology are being considered to improve supply and environmental friendliness.

Power reach to rural areas has been made possible by the rural electrification policies, through subsidies and by successfully extending the power grid to remote areas. Rural India lags behind urban areas in the consumption of power. Village electrification has made rapid strides in terms of numbers, but village electrification simply represents the presence of transmission lines that run into a village and hence the potential for electrification in the village for potential consumers. Household electrification has improved steadily over the years. Directed programmes to provide electricity to poor and under-privileged communities have reduced inequality in access to power. Agricultural electrification has been a success story considering the difficult terrain and fragmented farmlands and has been a significant factor in increasing productivity. This has been made possible through political will, investment and subsidies.

The quality of power is poor and unreliable in villages, leading to damage to pump-sets. **Table 9.19** reveals that even in 2004 only two states — Himachal Pradesh and Kerala — supply power all through the 24 hours of the day to rural areas.

Table 9.19: Power Supply to Rural Areas, India, 2004

Region/States	Average Hours of Supply per Day
Himachal Pradesh	24 hours
The Punjab	9 hours 43 minutes
Rajasthan	16 hours
Uttar Pradesh	14 hours
Uttaranchal	24 hours, except at Hardwar where it is for 20 hours
Gujarat	8 hours (Three Phase) and 14 hours 15 minutes (Single Phase)
Madhya Pradesh	4 hours 20 minutes to 5 hours 20 minutes (Three phase) and 5 to 10 hrs (single phase)
Maharashtra	15-16 hours for 15 days and 17-18 hrs for other days (Single / Three Phase).
Chhatisgarh	Nil
Andhra Pradesh	9 hours (Three Phase) and 7 hours (Single Phase)
Karnataka	6-11 hours (Three Phase) and 5-10 hours (Single Phase)
Kerala	24 hours (Three Phase)
Tamil Nadu	14 hours (Three Phase) and 10 hours (Single Phase)
Bihar	15 hours 30 minutes
Jharkhand	About 20 hours
Orissa	About 20 hours (private distribution company)
West Bengal	About 20 hours

Note: Data is not available for Haryana and J & K

Source: www.indiastat.com

Rural enterprise electrification is still quite low and has not kept pace with the other sectors. Decentralised renewable energy has been seen to be the direction to go in rural areas that are harder to reach through transmission and distribution lines from a central plant, as well as for sustainability and environmental friendliness. India is one of the world leaders in renewable energy programmes. At this point renewable energy sources represent a minute fraction of total power consumed but this share is expected to grow.

The power diffusion index for the energy sector is designed to reflect penetration of power in rural India in different sectors of users and to view progress over time. This index indicates an improvement in access to power from 25 % to 65 % in rural areas over the period 1981 to 2001.

An important finding of this study is the need for data availability for rural India. The best and most commonly used measure of electricity consumption in similar studies is per capita kilowatt-hour (kwh) consumption. This data is either not maintained or is not easily accessible. The quality of data available is systematically poor and unreliable.

Appendix

Sl. No:	Technology	Worldwide Status	Status in India
1.	PC firing with SOx and NOx control system	Commercialised	NOx control Commercialised SOx control Commercialised
2.	AFBC Power Plant	Commercialised up to 165 MWe (USA)	2x10 MWe units operating
3.	CFBC Power Plant	Commercialised up to 250 MWe (France)	1x30 MWe unit commissioned by BHEL-URGI Maharashtra (1997); 2x110 MWe in Gujarat
4.	PFBC Power Plant	Demonstration units up to 130 MWe (Sweden, Spain, USA, Japan)	Bench-scale R&D at BHEL and IIT Madras
5.	(i) IGCC Power Plant	Demonstration units up to 250 MWe (USA, the Netherlands)	6.2 MWe demo plant at BHEL, 600 MWe. conceptual design at IICT Hyderabad; Gasifier pilot plants at BHEL and IICT; Proposal for a 100 MWe demo plant by CSIR with the government
	(ii) Hybrid IGCC Plant	Pilot plant R&D (UK)	No activity
6.	Fuel cell based PFBC Power Plant	Advanced R&D	On-going R&D in fuel cells
7.	MHD based combined cycle Power Plant	R&D suspended in Russia and USA, ongoing in Israel	Pilot plant in BHEL, R&D terminated
8.	PC Fired Supercritical Power Plants	Commercialised up to1000 MWe	First unit being planned by NTPC/BHEL
9.	Slagging Cyclone Combustion Technology	Advanced R&D	Lab Scale StudiesR&D terminated
10.	Coal Beneciation	—	Three coal washeries proposed at Piparwar, Bina and Kalinga, one in operation
11.	Coal water slurry (CWS) combustion	—	R&D on CWS preparation and combustion at laboratory level at CFRI, Dhanbad and Fuel Evaluation Test Facility (FETF) in BHEL, Tiruchi. Work stopped.
12.	Re-powering technology	Several successful projectsimplemented abroad	National programme in place

Source: Kolar and Sastri (1999)

REFERENCES

Central Electricity Authority (CEA). 1961–2001. *All India Electricity Statistics*. New Delhi:Government of India.

Centre for Monitoring of Indian Economy (CMIE). Various years. *Monthly Review of the Indian Economy*. Mumbai: Economic Intelligence Service.

Chopra, S. K. 2004. *Energy Policy for India: Towards sustainable energy security in India in the twenty-first century*. New Delhi: Oxford & IBH.

Dadhich, P. "Indian Power Sector". Undated article, TERI website.

Economic Census 1980, 1990 and 1998. New Delhi: Government of India, Ministry of Statistics and Programme Implementation.

Economic Survey. Various years. New Delhi: Government of India, Ministry of Finance.

Indian Council of Agricultural Research. 2004. *Agricultural Research Data Book 2004*. NewDelhi: Ministry of Agriculture, Government of India.

Kolar, Ajit Kumar and V.M.K. Sastri. 1999. *Advanced Coal Technologies for Power Generation in India*. Bangalore: National Institute of Advanced Studies.

Ministry of Non-conventional Energy Sources (MNES). Various years. *Annual Reports*.New Delhi: Government of India.

Nagaraj, R. 2006. "Public Sector Performance since 1950: A fresh look". *Economic and Political Weekly*, Volume XL1, No. 25.

National Council for Applied Economic Research (NCAER). 1986. *Socio-economic Impact of Rural Electrification in India*. New Delhi: NCAER, sponsored by International Labour Office, Geneva.

National Sample Survey Organisation (NSSO). 50th Round. 1993–94. Report No. 410/2. *Energy Used by Indian Households*. New Delhi: NSSO.

———. 51st Round. 1994–95. *Unorganised Manufacturing Enterprises in India: Salientfeatures*. New Delhi: NSSO.

———. 55th Round. 1999–2000. Report No.464. *Energy Used by Indian Households*. NewDelhi: NSSO.

Planning Commission. 2002. *Annual Report on the Working of the State Electricity Boards and Electricity Departments, 2001–02*. New Delhi: Government of India.

———. 2005. *Mid-term Appraisal of Tenth Five Year Plan (2002–2007)*. New Delhi:Government of India.

Srivastava, G. 2000. *Renewable Energy in Agriculture*. New Delhi: Indian Council ofAgricultural Research.

The Energy Research Institute (TERI). 2001-02. *Annual Report*. New Delhi: TERI.

UNCTAD. 1987. *Technology Issues in the Energy Sector of Developing Countries*.Geneva: UNCTAD.

World Bank. 1979. *India: Economic Issues in the Power Sector*. A World Bank CountryStudy. Washington: World Bank.

www.cea.nic.in

www.censusindia.net

www.indiastat.com

10

SUMMING UP

The MSSRF study on *Measures of Progress of Science and Technology in India* has explicated a perspective on the process of the development of the Indian economy. This perspective, in broad terms, states that significant technological achievements have been accomplished by the major sectors of the Indian rural economy in the post-Independence period, and that these achievements have been essentially related to specific interventions by the state. Given this perspective, the study has provided an analytical documentation of significant catalytic technological interventions across sectors, developed by the public research system and promoted by the government.

The varietal improvement programme, with its focus on developing varieties of crops with desirable characteristics, has been identified as the catalytic technology in the sphere of crop husbandry. In the case of cattle and buffalo, a combination of technologies pertaining to breeding, health, feed, and marketing have been significant, while technologies pertaining to breed and feed have been important in the poultry sector. Carp culture has been identified as the most strategic intervention in the area of inland fisheries. Thus, in the production-related sectors, namely, crop husbandry, animal husbandry and fisheries, the catalytic technologies have been those that have brought about significant changes in output (crop production, milk production, egg production, fish production) by improving land productivity or animal productivity or water productivity.

The chapter on crop husbandry discusses in detail the varietal improvement programmes with regard to nine crops, emphasising the various dimensions. While improving yield levels has been the underlying tenet of the programme across crops, other important dimensions such as improving quality, developing resistance to biotic and abiotic stresses, altering the duration of maturity, and developing photoinsensitivity have also been major focus points. Appropriate indicators such as yield, production and value of output have been chosen to measure the impact or achievements triggered by the varietal improvement programmes in the sphere of crop husbandry. Further, an index of technology achievement has been computed using the value of output per hectare as the indicator for the period 1950–51 to 2000–01. The technology achievement index for the crop husbandry sector as a whole has more than doubled over the five decades; the index has increased for the individual crops too, with the extent varying across crops.

Growth in the crop husbandry sector is also essentially linked to developments in irrigation, as water is the lifeline of agriculture. Several technologies, in areas such as dam construction, sub-surface drilling, pump manufacturing, water conservation techniques, etc., have been responsible for rapid strides in the irrigation sector.

With regard to animal husbandry, in the dairy sector, the value of milk per milch animal and in the poultry sector the productivity per layer have been used as indicators in the computation of technology achievement. The technology achievement index for the dairy sector has doubled over four decades since 1961–62, while that for the layers has increased from a base of 100 to 235 from 1961–62 to 2002–03.

In fisheries, while the introduction of carp culture resulted in improving the productivity per unit area of water, fish production has been used as the indicator of technology achievement for want of productivity data. Carp production increased more than fourfold over the 14 years, 1986–2000, while total fish production increased more than eightfold, from 7.3 lakh tonnes in 1951–52 to 59.5 lakh tonnes in 2001–02.

The chapter on forestry discusses the major technological interventions that have been initiated in various spheres of forestry in India in order to manage forests in a sustainable manner. Strategies have been adopted for *in situ* and *ex situ* conservation with regard to conservation forestry while the technology developed for rehabilitation of mangroves as well as the Joint Forest Management programme have been important interventions in the sphere of restoration forestry. Clonal technology, plantation programmes and agro-forestry have been major contributions in the area of production forestry while in wildlife management and protection, several technologies such as radio collaring, conservation genetics, DNA technology etc. have been the main inputs. While various technological interventions have promoted forestry in post-Independent India, given the complexity of forestry there has been no attempt to compute an index of technological achievement.

The chapter on health sets out the technical and managerial aspects of various health programmes initiated by the government, with regard to major health diseases of rural India. The impact of national health programmes initiated to control or eradicate major diseases (malaria, leprosy, tuberculosis, cholera and diarrhoeal disorders, HIV/AIDS, poliomyelitis, measles, blindness, etc.) have been measured by the decline in prevalence or incidence of the diseases over time. The perceptible decline in rate of incidence of all the major diseases over the last forty to fifty years is a significant achievement of the government initiatives. In addition to the analysis of impact of various health programmes on specific diseases, one indicator has been used as a summary measure of achievements in the overall health status of India's rural population: the 'expectation of life at birth', which has increased from 48 years in 1973 to 61.2 years in 2000, on an average, for a rural Indian.

The discussion on drinking water provides an analysis of the role of technology in the rural water supply programme and traces the progress in the provision of drinking water to India's rural population. The development of Mark II and Mark III hand-pumps has greatly contributed to the Indian rural water supply programme, as have other technological tools adopted for geophysical investigations, for testing, monitoring or improving water quality and for sustainability of water resources. There has been significant progress in the coverage of rural water supply over the 1980s and '90s, seen in terms of access to drinking water for rural people, rural households and villages.

Major technological interventions in conventional as well as renewable energy sources have led to the progress in supply of power and the consequent improvement in consumption of power across different sectors in the rural economy. The impressive growth in power generation — from 6.6 billion kwh in 1950–51 to 554.5 billion kwh in 2000–01 — can be attributed to planned investment and indigenous capacity building in India. Details of progress in rural electrification indicate that power usage by households and agriculture has increased rapidly and the power diffusion index shows an improvement in access to power from 25 % to 65 % in rural areas over the 1980s and 1990s.

While this study has attempted an explication of the perspective that significant technological achievements have been realised by the major sectors of the Indian rural economy, it is far from our contention that it has done justice to every dimension of the enquiry. First, the study has analysed the impact of technological interventions in very broad terms and there has been no attempt to isolate the pure effect of technology. This is partly due to the fact that the purpose of the study has only been to highlight the achievements triggered by state-supported technological initiatives and not to separate the effect of catalytic technologies from the overall results. The isolation of the outcome of just the catalytic technologies is an extremely difficult task given the availability of data. For instance, the varietal improvement programme has been identified as the catalytic technology as far as crop husbandry is concerned and in order to understand the impact of varieties it is essential to have some basic data on level of adoption of various varieties as well as their yield performance in the fields. This data has not been collected in any systematic fashion in our country, either at the national or regional level, nor has there been an effort to compile and publish the data available in scattered sources. Similarly in the dairy sector while cross-breeding has been a strategic technological intervention, details of cattle or buffalo population have not been made available breed-wise. Such examples of gaps in data can be given for every sector that has been studied here.

Second, our study has not examined the reasons for the variance between potential and actual productivity or that between international levels of productivity and corresponding Indian levels.

Third, while the study has analysed the role of public-funded research in the development of various catalytic technologies, there has been no substantive investigation of various other policies that were put in place to successfully operationalise the catalytic technologies. For instance, in the discussion on crop husbandry, we have not examined other policies that were initiated by the state (pertaining to rural credit, minimum support price for crop produce, improvement of irrigation, etc.) in order to popularise the new crop varieties released to farmers.

Fourth, technological achievement has been analysed in isolation from the social and environmental impact of technology. For instance, while the achievement triggered by the varietal improvement programme would vary a great deal across regions, across crops and across different sections of farmers, this has not been dealt with. Similarly, the environmental impact of technologies has also been brought in only marginally, say, in the discussion on the negative impact of irrigation. However, the examination of the social and environmental impact of technology would require a separate detailed line of investigation.

Limitations apart, we have documented the unambiguous progress in production with regard to crops, milk, eggs and fish, improvement in health status, and growth in access to electric power and drinking water for India's rural population over the post-Independence period. These achievements are a result of the proactive role played by the state in promoting R&D that has contributed the technologies crucial for a breakthrough in production and promotion of people's access to basic facilities. However, the analysis clearly shows a tapering of growth in the 1990s compared to the 1980s in the major sectors of the rural economy. The rate of growth of yield of almost all major crops as well as the growth rate of milk, eggs and fish production have declined in the 1990s. This has very serious implications for the food security of the people and indicates the necessity for state intervention.

The National Agricultural Research System (NARS), developed and strengthened to address the various challenges that face agriculture from time to time, has clearly made positive contributions to the rapid increase in food production (foodgrains, milk, eggs and fish) in the decades since Independence. Given this, it is imperative that the current concern of the declining rate of growth in agricultural production receives urgent attention from NARS. Moreover, agricultural research in the early part of the 21st century also faces the challenges regarding the adoption of Intellectual Property Rights and assessment of bio-technology advances, and this is yet another reason why the role of the state becomes crucial to safeguard the interests of millions of farmers. However, public domain research is not independent of the larger macro economic policies pursued by the state. Given that in general the neo-liberal policies pursued by the Government of India since the early 1990s promotes the withdrawal of the state, there is a danger that all the 'achievements' that have been elaborated in this study will be allowed to collapse over the coming years. Therefore, it is imperative that appropriate measures are taken to reverse the declining trend in agricultural growth in order to have an agricultural renewal in the country.

M. S. Swaminathan Research Foundation
Centre for Research on Sustainable Agricultural and Rural Development
3rd Cross Street, Taramani Institutional Area
Chennai – 600 113, INDIA

सत्यमेव जयते

Office of the Principal Scientific Adviser to the Government of India
Vigyan Bhawan Annexe,
Maulana Azad Road
New Delhi-110 011