Journey of MSSRF

Harnessing Science for Sustainable Development

innovations and impacts

M S SWAMINATHAN RESEARCH FOUNDATION

August 2019

Innovations and Impacts
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Innovations and Impacts

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About this Publication

This publication on the 30th year milestone of M S Swaminathan Research Foundation (MSSRF) highlights the innovations and impacts resulted from the organization in the last three decades of its journey in the light of the 2030 Sustainable Development Goals (SDGs). We believe, the Key Result Areas described in this publication are comprehensive in building sustainable livelihoods of local communities, achieving nutrition and health security, and, in securing on-farm conservation of the vanishing crops and varieties across diverse agro-ecological systems.

Twenty-five selected interventions that have completed 10 or more years of implementation and offered concrete lessons and knowledge are described and analysed under six Key Result Areas- (i) Integrated Coastal System Management; (ii) Biodiversity Conservation, Sustainable use and Benefit Sharing; (iii) Biotechnological tools for improving agriculture productivity; (iv) Eco-technologies for promoting a bio-village paradigm of human development; (v) Food and Nutrition Security, and (vi) Village Knowledge Centres - in this publication. From this publication, the reader can find pertinent ideas, methods and approaches for designing and implementing projects that are SDG oriented and local community centric, and as scientific and strategic in sustainable livelihood improvement. The strategic way forward plan has been identified based on the lessons from the past 30 years, and positioned in the emerging context of global climate change and nutrition and health security.

The purpose of this publication is to reach out to the key stakeholders in the area of sustainable agriculture and rural development and stimulate necessary policy actions towards upscaling some of the key achievements of MSSRF. The publication also has the potential to influence other organizations, working in India and elsewhere in developing countries, in learning implementation of the SDG provisions related to sustainable and equitable development within reasonable time and available resources.

We hope this publication will serve the intended purpose of reaching out to the targeted audience in the area of sustainable and happy human development. We take this opportunity to thank all our donors and partners for the support extended to us and involvement in carrying forward our work for three decades. We look forward to receiving your comments and suggestions for improving the outreach of MSSRF programmes.

N. Anil Kumar
Executive Director, MSSRF

July 31, 2019

Preface

In 2019, the M. S. Swaminathan Research Foundation enters its thirtieth year. This year also marks the beginning of the UN decade of sustainable development, with its programme to achieve 17 SDGs by 2030. This is an appropriate occasion for the MSSRF team to review progress made in the area of sustainable agricultural and development. Over the last three decades, MSSRF has undertaken a range of integrated interventions in partnership with rural, tribal, and coastal communities that have contributed to increase in agricultural production, better natural resource management, and improved livelihoods. MSSRF has also played a role in policy design at local, national, regional and international levels especially with respect to farmers' rights, food and nutrition, coastal area management, and biodiversity conservation.

In the last 30 years, MSSRF has implemented more than 300 projects, with support from national and international donors. The programme of work has been shaped by inputs from peers and external reviewers, as well as partners in the community.

This booklet recounts some of the innovative contributions of MSSRF, especially at the policy level under six broad heads: Integrated coastal system management; Biodiversity conservation; biotechnological innovations; Ecotechnology; Food security and nutrition; and Village knowledge centres. I invite you to read this booklet, titled "Innovations and Impacts'.

We seek your ideas and partnership to plan our activities for the next 10 years, in the context of achieving the SDG of Zero Hunger.

Madhura Swaminathan
Chairperson, MSSRF, Chennai

1 Aug 2019

FOREWORD

Genesis and Growth of M S Swaminathan Research Foundation

In 1969 Sir C V Raman stayed with us in Delhi for a couple of days on his way to Kanpur. The house where I was staying at that time had a beautiful collection of roses largely because of Dr B P Pal's love for Roses and Bougainvilleas. During the course of our conversation over lunch in the rose garden, Sir C V Raman mentioned that he has some land in Bangalore which he can make available to me for establishing a National Centre of Plant Genetics. He asked me whether I am interested in building an institute in the field of biology similar to that of the Physics Institute which he has established. I then mentioned to him that I will certainly keep this in mind when I retire from service. Also, at that time, I was fully occupied with issues relating to the green revolution.

My last formal assignment was the position of Director General, International Rice Research Institute, The Philippines. I was there from 1982-88. In the year 1988, I received the First World Food Prize which had a cash award of two hundred thousand US dollars. After returning to India, I started serious efforts to implement the promise I had given to Sir C V Raman. There were several offers of land and money to establish an Institute of Plant Genetics. After considering various locations, I chose Chennai because we wanted to work on coastal ecosystem. Tamil Nadu has a shoreline of over thousand kilometers. The Tamil Nadu government was kind enough to offer land in the Taramani Institutional Area for the main building of the Foundation and thus was born the M S Swaminathan Research Foundation (MSSRF) in 1988. The funds I received from the World Food Prize were helpful to build a minimum essential infrastructure for our scientific work. My only regret is that I could not start the Centre during the life time Dr C V Raman.

The journey began on May 17, 1988 with a Not for Profit Scientific Trust being registered under the Indian Trust Act in New Delhi. After several consultations, we decided that MSSRF should aim to fill critical gaps in ongoing research in the field of agriculture. This is how the following areas were chosen for attention:

- Coastal Systems Research involving concurrent attention to inland and coastal fisheries with particular reference to mangroves
- In-situ on-farm conservation of biodiversity
- Biotechnology with a view to transfer genes across-sexual barriers with particular reference to developing material for withstanding the potential adverse impact of a rise in sea level caused by global warming
- Development of Ecotehnologies which involve mainstreaming ecology in technology development and dissemination (now carried out at the JRD Tata Ecotechnology Centre)
- Building models for sustainable development; this lead to the establishment of Biovillages initially in Puducherry
- Training and capacity building in the area of sustainable development with particular reference to food and nutrition security.
- Providing facilities for post graduate scholars to do their Ph.D. work.

Over the years these areas have been found to be very relevant to the current needs of rural and tribal families and concentrated on six inter-disciplinary themes.

The priorities for the action agenda had been dealt over years under six interrelated and inter-disciplinary programme areas. The **Coastal Systems Research**, which designed on the model of Farming System Research was the first area of concern and brought in an integrated management approach by land and sea surface on the one hand, and to capture and culture fisheries and forestry and agro-forestry on the other. Further, as the priority research domain to deal with the issue of sea level. MSSRF has established a national and global position of leadership in this area over the past 30 years.

Biodiversity conservation, sustainable use and equitable sharing of benefits have been a major area of research from the very inception of MSSRF. The priorities of this programme were promotion of community conservation methods; saving agro-biodiversity especially traditional varieties and landraces, endangered plant species focusing on one of the Global Hotspots of Biodiversity - the Western Ghats and Developing a model for 4C approach (conservation, cultivation, consumption and commerce) integrating conservation and commercialization approach. The significant contributions at the policy level include preparation of the initial drafts of both the Protection of Plant Varieties and Farmers' Rights Act 2004 and the Biodiversity Act 2002 at MSSRF.

Biotechnology is another important programme of MSSRF function with an application perspective in sustainable and resilient agriculture development. Establishing a Genetic Garden for mainstreaming nutrition in farming systems, assessing the diversity of plant and microbial species for abiotic stresses and disease control using biotechnological tools.

The **Ecotechnology programme** (i.e. appropriate blend of traditional wisdom and ecological prudence with frontier technologies), based on five E's (Ecology, Economics, Equity, Employment and Energy) evolved to develop models on operationalizing the concepts of Sustainable Development leading to the establishment of the JRD Tata Ecotechnology Centre with the generous support of Tata Trusts. Participatory research and development, Knowledge management and institution building are the important pathways to integrate the classic and contemporary in scientific strategies. This led to institutions like the Bio-village, Ecoenterprises, Village Knowledge Centre (VKC), Community Water Security systems etc., for converting concepts into field level accomplishments.

The emphasis on food and nutrition security and gender mainstreaming led to the establishment of the B V Rao Centre for **Food Security** and the Uttara Devi Centre for **Gender and Development** respectively. As MSSRF's human centred development programmes and pro-poor and pro-nature biotechnology initiatives made progress, it became evident that the basic problems of rural societies like poverty-induced under-nutrition, gender discrimination, and income, and health insecurity will have to be addressed, if the ultimate goal of hunger and poverty free villages is to be achieved. This led to the organization of Mission 2007: A Hunger-free India. Thus, MSSRF's capacity to address the two basic issues of nutrition and education was built-up.

Among technologies, it was decided on the basis of inter-disciplinary dialogues to accord priority to Ecotechnology for Biovillages and **Information Communication Technologie**s. Rural Knowledge Connectivity was considered an essential pre-requisite for rural upliftment. This led to the evolution of Village Knowledge Centres and establishment of the Jamsetji Tata National Virtual Academy for Rural Prosperity and the organization of the National Mission 2007: Every Village a Knowledge Centre.

MSSRF started its work in 1989 in the laboratory kindly provided by the Indian Institute of Technology, Chennai. It later moved into a rented building in Kotturpuram and then to its present location in Taramani, Chennai in 1993. Apart from creating excellent facilities for scientific work and for training, MSSRF strengthened its ecological outreach by establishing the following centres:

- Biovillages supported by a Biocentre at Puducherry (1990)
- Coastal Systems Research on mangroves and

coastal agriculture in Chidambaram (1990)

- Community Agrobiodiversity Centre, Kalpetta, Wayanad, Kerala (1997)
- MSSRF at Kolli Hills, Tamil Nadu (1994)
- Biju Patnaik Medicinal Plant Garden and Research Centre, Koraput, Odisha (2004)
- Fish for All Research and Training Centre at Poompuhar, Tamil Nadu (2007)

In addition to its own facilities MSSRF has been collaborating with a wide range of government and non-government organization having similar objectives.From a humble beginning, the organization has grown into a World Class Centre in sustainable agriculture and rural development research and action. MSSRF has now 200 plus staff members from multiple disciplines, and presence in over 15 states of India with a reach of ~300,000 small holder farm families.

This year 2018-2019 marked the thirty year of milestone of MSSRF- an organization founded for the purpose of spearheading an *Evergreen revolution* in the country.

On the occasion of our 30th anniversary of MSSRF, I express my gratitude to the Trustees (past and present), donors, scholars, scientific and administrative staff for helping making MSSRF a centre without walls, available to all those who need the knowledge and expertise in the foundation.

Several donor agencies and individuals supported the growth of MSSRF. My sincere thanks go to all of them, but for their support the organization wouldn't have reached to this milestone. I take this opportunity to thank all our community partners for the relentless support extended to us and involvement in carrying forward these three decades.

The present publication summarizes the work done during the last thirty years. This publication is specially designed to indicate the impact of MSSRF's work on translational research. It should be emphasized that only interaction between technology and society that can help to accelerate sustainable development

We look forward to continue serving you and working together with you!

M. S.Swaminathan
Founder Chairman, MSSRF
Chennai/August 1, 2019

Journey of MSSRF

1987: The World Food Prize

1988-1993	1993-2000	2000-	2018	2019-2030
The Early Years	Gaining strength	Consolidation and Expansion		Ongoing and Looking Ahead
1988 May 27, Registration in New Delhi 1989: Chennai HQ: Anna University & IIT; Rented building in Kotturpuram; 1993 April 14: Moving to own campus in Taramani 1991: The Honda Prize for Eco-technology & The Tylor Prize for Environment Achievement;	Implemented a large number of key Projects supported by International and National agencies: ITTO; UNDP, FAO, UNESCO, UNIDO, ADB, IFAD, SIDA, SDC, IDRC, TATA trust DBT, CAPART Ford F, Mc Arthur F, Summit F. 1994 UNEP Sasakawa EP; 1996: The Blue Planet Prize for MSSRF 1999: Volvo Environment Prize	Coastal System(CS) Research for Sea level rise adaptation BD conservation and Enhancement for community development Biotechnologies for Sustainable Agriculture Eco-technologies & Information Education and Communication for Technologies Sustainable livelihoods Food & Nutrition Security, Networking and Advocacy - Mission 2007: Hunger Free India Mission 2007: Every Village a Knowledge Centre Grameen Gyan Abhiyan	CS & Climate Change Program in East Coast and West Coast & Fish for All Centre for sustainable small scale fisheries. Biotechnologies for abiotic stress management Community Agro-biodiversity Centres; Sustainable and Climate resilient agriculture in different agro-ecosystems Farming System for Nutrition and Health	PAN-INDIA Programs to achieve the SDG of Zero Hunger with geographic focus on the hotspots of poverty and hunger in the southern and central part of India, the Eastern Ghats, & the North-east region Mission 2030: Every Village A Biovillage

2018: The World Agriculture Prize

Chapter I

Integrated Coastal System Research and Management

The Coastal System Research (CSR) was selected as the first area of concern to MSSRF. India has over 7500 km of shore line and several islands but no organization was giving adequate attention to the integrated management of land and sea surface on the one hand, and to capture and culture fisheries and forestry and agro-forestry on the other. Further, the prospects for sea level rise as a result of global warming and the consequent melting of glaciers, Arctic, Antarctic and other ice caps, are real. CSR was designed on the model of Farming System Research to provide the scientific basis needed for fostering a community-centred and process-oriented approach to conserve, restore and sustain mangrove wetlands.

The tsunami of December 26, 2004 underlined the urgency of introducing in coastal areas an integrated development-cum-disaster management programme comprising bio-shields, bio-villages, knowledge centres and sea water farming with salt tolerant crops. As a long-term response to the post-tsunami needs and vulnerabilities of coastal communities, a "Fish for All" Training Centre came into existence. The Centre is designed to build the adaptation capacity of coastal families by providing training in creating coastal bio-villages with integrated livelihood opportunities.

The programme provides the scientific basis needed for fostering a community-centred and process-

oriented approach to conserve, restore, and sustain mangrove wetlands and other coastal vegetation. Community restoration techniques such as raising community nurseries, systems of raising agro-aqua farms through integrated production of prawns and fish and raising mangrove plantations received particular emphasis. Monitoring of the status of mangrove wetlands through remote sensing is a continuous process at the organization. As central to the programme initiative, MSSRF has established a national and global position of leadership in this area over the past 30 years. It can now build on the lessons learnt to make integrated coastal zone management a national practice.

1. Joint mangrove conservation and management for ecological and livelihood security

Between 1980 and 2000, human activity had reduced the area of mangroves by 26%, from 5.7 to 4.2 million ha, in the five countries most affected by the 2004 tsunami. From 1993-2002 MSSRF demonstrated a Joint Mangrove Management (JMM) approach to address the twin issues of failure in restoration of healthy mangrove forests and ensuring the participation of local communities for its sustainable management. The methods of scientific restoration and partnership with local communities and the Forest Department resulted in mobilizing nearly 5200 mangrove-user families into 33 village level mangrove councils in three states on the east coast of India. Nearly 1500 ha of degraded mangroves were restored with the planting of 6.8 million mangrove saplings. About 12000 ha of pristine mangroves were brought under joint mangrove management by this intervention.

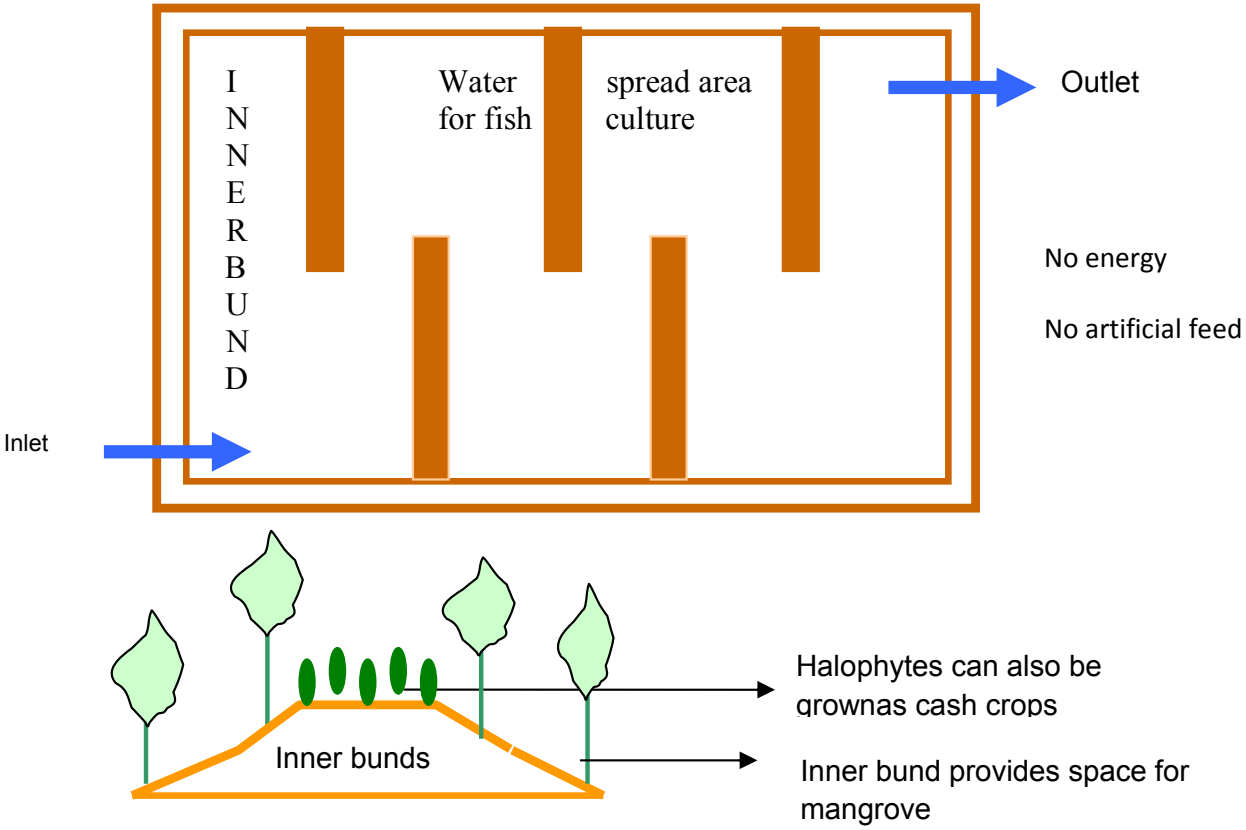
The Ministry of Environment and Forests, Government of India, recognized these pilots and included them in the National Mangrove Action Plan as the best scientific method and approach and advised the State Forest Departments to adopt this as a model for mangrove restoration and management. The State Governments of Tamil Nadu, Andhra Pradesh, Odisha, Maharashtra, Gujarat have been replicating this model since 2000. As per the assessment report published by the Forest Survey of India in 2016, the mangrove forest cover of India has increased by 7000 ha between 1987 and 2015 and the MSSRF led JMM programme played a catalytic role in bringing about such a remarkable increase.

Restoration of coastal mangroves and non-mangrove tree species will buffer communities from future tsunami events. In addition, it has a positive impact on fisheries and increases green cover. These benefits are not found in artificial coastal protection structures. During the 2004 tsunami, villages located behind mangroves suffered little damage in terms of loss of lives and property compared to the villages that were directly exposed to the sea. The paper on "The Asian Tsunami: A Protective Role for Coastal Vegetation", published in Science in 2005, helped change the perception of scientists, policy makers and planners regarding the protection of mangroves and other coastal vegetation. This subsequently resulted in increased attention and funding for mangrove conservation, restoration and management programmes in many developed countries.

2. Integrated Mangrove Fishery Farming System: A potential method to enhance the adaptive capacity of fishing communities to sea level rise

Integrated Mangrove Fishery Farming System (IMFFS), wherein cultivation of mangroves, halophytes and culture of fish are integrated, provides the tangible option of coastal aquaculture as a source of sustainable livelihood which also strengthens resilience of coastal communities to increasing sea level rise.

Fig 1: Design of a seawater based integrated agro-aqua farming system with inner bunds



The IMFFS farm is designed to create space both for raising mangrove trees and for the culture of fish, prawn or crab. It functions with very limited energy for its operation. Low energy consumption and zero use of artificial feed greatly reduce input cost and also avoid environmental pollution.
Sea water is exchanged daily by tides through gravitation pumping of water in and out of the ponds to maintain water quality. Daily exchange of water helps in maintaining oxygen content of the water and brings in a lot of fresh food in the form of planktons to the ponds. This helps avoid use of artificial feed. IMFFS was pilot tested by MSSRF in 20 ha, in Tamil Nadu and Andhra Pradesh, in which 1500 to 1800 Rhizophora saplings and 300 to 400 Avicennia marina saplings per hectare were planted in different sequences and heights. Culture of sea bass – a commercially important fish – was done in the pilot farms @ 1500 to 1800 finger lings of 8 cm length/ha in. The ponds are designed in such a way that they hold three to four feet of water at all times to support fish culture. The experimental results have shown that 30% to 35% of space for mangrove plantation and 70% to 65% for fish/prawn/crab culture is ideal in the integrated farm. At the end of two and a half years, the net income from the pilot testing was Rs. 65000 to Rs. 80000 in a period of six months.

Apart from economic benefits, the IMFFS pond also acts as a physical barrier against rising sea levels and thereby avoids inundation of sea water in land. The mangrove trees growing in the IMFFS function as a bioshield against cyclones. The United Nations Framework Convention on Climate Change (UNFCCC) and the German Corporation for International Cooperation (GIZ) have recognised IMFFS as one of the models to enhance adaptive capacity of coastal communities to sea level rise. The IMFFS model has also won the prestigious Earthcare Award instituted by the Times of India and Jindal Steel Works.

3. Strengthening below sea level farming systems

Kuttanad region in Kerala, spread over 100,000 hectares with more than 40% of reclaimed land from the backwaters and the Vembanad Lake, has been described as "the man-made land". The characteristic component of Kuttanad farming is below sea level. It encompasses wild and domesticated agricultural diversity existing in a multiplicity of habitats: genetic diversity of crops, livestock, harvested species of trees, fish, wildlife and other valuable species; and in maintenance of associated cultural traditions and knowledge systems. Recently the system has been under pressure owing to anthropogenic factors that have had a negative impact on water quality. Since 2012 MSSRF is working in the Kuttanad region with farming and fishing communities to have access to safe drinking water and clean environment. The projects in this direction have resulted in establishing over 130 rainwater harvesting tanks (each of 10,000 litres) and a Community Water Knowledge Centre that aims at educating the public on water conservation and pollution in the region. After the 2018 Kerala flood, MSSRF joined the Kerala Government to re-build this worst-affected region with the support of the HDFC Bank's Corporate Social Responsibility (CSR) wing under their Holistic Rural Development Programme.

On the basis of MSSRF's study and proposal, Government of Kerala established an International Training and Research Centre for developing sustainable management of this unique farming system. Most importantly, FAO recognized the Kuttanad Below Sea Level Farming System as a "Globally Important Agricultural Heritage Site".

4 Halophytes[1]: the future crop for coastal areas

About 29 halophyte species were collected from the coastal areas of Tamil Nadu and Andhra Pradesh and a halophyte genetic garden was developed at Vedaranyam. Of the 29, three species (*Salicornia brachiata, Suaeda maritima* and *Sesuvium portulacastrum*) were selected to study feasibility of their cultivation under field conditions, using saline water. Agricultural fields, degraded due to commercial aquaculture, having a salinity level of 6.5 dS/m (4.16 ppt) at 25°C with higher percentage of sodium and potassium levels, were used. The water used for irrigation had salinity ranging from 23 to 28 ppt. These trials, resulting in a harvest of about 23 t/ ha of *Salicornia brachiata* (fresh weight), 17 t/ha of *Suaeda maritima* and 9 t/ha of *Sesuvium portulacastrum*180 days after

1 Halophytes are plants that survive to complete their life cycle in higher salinities. Many of the high saline tolerant halophytes can be grown in the farms irrigated with seawater to produce edible oil, vegetables, medicinal plants and flowers, or as fodder and raw materials to produce various fine chemicals and new products, apart from other minor uses.

planting, proved that these halophytes have a great potential for cultivation as commercial crops.

5. The Fish for All (and Forever) Centre

A Fish for All (and Forever) Research and Training Centre with a state-of-the-art fish pre-processing unit (with hazard analysis and critical control points) was established in 2009 in Poompuhar village of Tamil Nadu with the support of Tata Trusts. The Centre emerged as a platform for multi-stakeholders for undertaking both practical action and advocacy to influence public policy aimed at sustainable management and protection of marine and coastal ecosystems. It is now emerging as a Community Centre with active involvement of all stakeholders: fishing families, boat owners, fish traders, seasonal or part time fishers, local traditional authorities, elected government officials, line departments, non-governmental organizations and financial institutions. The Centre in partnership with the Tamil Nadu State Fisheries Department, fisheries colleges and the National Coast Guard organizes training and capacity building with the aim of achieving SDG 14. The focus of the Centre is in the following three major areas:

Sustainable small-scale capture fisheries and resource enhancement: Promoting and demonstrating various technologies for sustainable use and management of coastal fishery resources is a major focus area of the Centre. The community based artificial reef programme is one of the major initiatives in resource management. This aims to develop a village level co-management plan, involving key stakeholders, for better planning of fisheries resource management. The flagship programme in capture fisheries is the Fisher Friend Mobile Application (FFMA) which, in 2019, reached over 49,000 fishers across eight states. It provides ocean state information, including early warning through mobile, apart from information on potential fishing zones and sustainable fisheries. This ensures fishers' safety as well as maximum profit from each fishing operation.

Post-harvest management and value addition: In recent times, due to the entry of large-scale players in fish processing and marketing, there is a shift towards fishing sector becoming more commercial and export oriented. As a result, women are being totally marginalized in fish marketing and processing, while the middlemen siphon off the bulk of benefits. In order to address the issue, the Centre facilitates marginalized women fish vendors through a collective approach by forming institutions. Also, capacity-building programmes are organized to equip them to become successful entrepreneurs, through technological and knowledge empowerment, to compete in the markets. The incubation centre at the unit helps women to learn hygienic fish processing, value addition, improving quality of raw fishes,

FFMA: a life-saving tool for small-scale fishers

The Fisher Friend Mobile Application (Fisher Friend) is an android application developed in collaboration by MSSRF, Qualcomm, ASTUTE Technology and Tata Consultancy Services. This App delivers messages to fishermen in vernacular languages on wave height, wind speed and direction and potential fishing zone, GPS for safe navigation, marking marine resources and risks zones, market information, dragging fish net area, emergency contact numbers and government schemes. Fisher Friend Mobile Application's journey began with a modest number of 40 users in the state of Tamil Nadu and Puducherry. Over a period, the application has spread across eight coastal states and one Union Territory benefitting over 49,000 users from 66 coastal districts in India. The journey continues and envisions reaching every marine fisher in the country. The coalition with Indian National Center for Ocean Information Services, local traders, state governments resulted in this scientific information and knowledge package covering the last mile. The 48-hour forecast information of the ocean state helps fisher folk to plan their fishing trip well in advance and avoid potential risks to their lives and livelihood assets. For example, Siva Sankaran of Samathanpettai village from Nagapattinam district said that "… human life is very precious; it cannot be brought back to life once it is lost, whereas one can earn money even [if] he/she loses the entire property. So, we attach high value to Fisher Friend and we feel that it is our moral responsibility to share this FFMA app with each and every one of our fisher folk in our village".

developing entrepreneurial skills and extending support for forward and backward linkages to sustain the business.

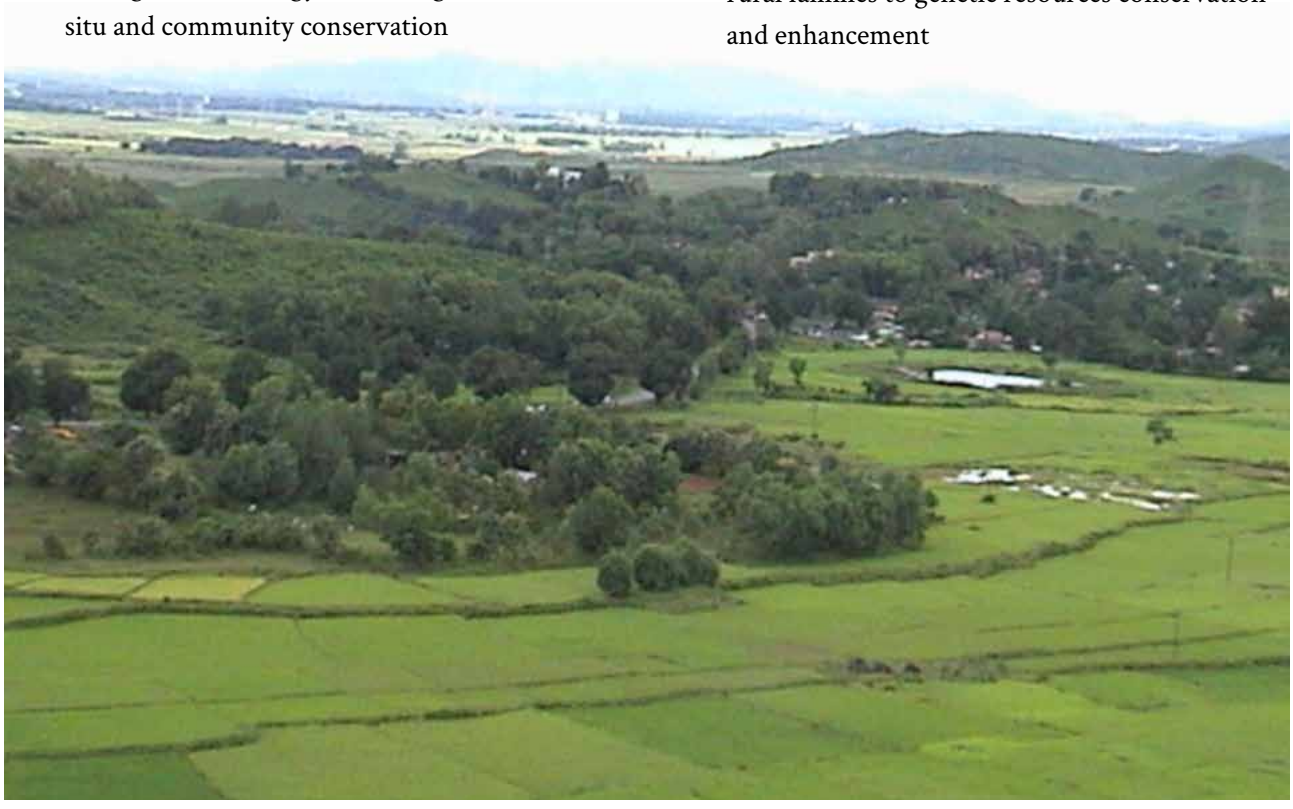
Culture fisheries resource enhancement and management: The continuous failure of the monsoon in recent years has placed small farmers in the coastal region under stress due to poor returns from agriculture. One of the strategies demonstrated for addressing this issue is integrating aquaculture with the farming system and promoting low input sustainable fish culture techniques among small-holding farmers. This technology involves integration of fish polyculture with crop and livestock to optimize the use of on-farm resources and to minimize the use of external production inputs. The integration helps to secure higher income, farm employment and reduced risk in production.

Chapter II

Biodiversity Conservation, Sustainable Use & Benefit Sharing

The conservation, sustainable use and equitable sharing of benefits has been a major area of research from the very inception of MSSRF. Significant contributions at policy level include preparation of the initial drafts, at MSSRF, of both the Protection of Plant Varieties and Farmers' Rights Act 2004 and the Biodiversity Act 2002. Getting an integrated Act covering both farmers' and breeders' rights on the model of the one prepared at the 1996 Dialogue has been a major policy achievement, with no parallel in the world. At the field level, the major contributions were the following:

- Development of an Integrated Gene Management Strategy, consisting of in-situ, ex-situ and community conservation
- Revitalisation of community conservation traditions through community and field gene bank, seed bank and grain bank (conservation – cultivation – consumption chain)
- Generation of an economic stake in conservation through participatory breeding and linkage with markets
- Enlarging the food security basket by including in the diet underutilized crops like millets, tubers, grain legumes and leafy vegetables
- Development of methodologies for reward and recognition of the contributions of tribal and rural families to genetic resources conservation and enhancement



- Undertaking a gender audit of the implementation of the two Acts
- Building awareness among NGOs about implementation of Farmers' Rights
- Partnership with selected Panchayati Raj Institutions in the Western Ghat area to equip them to implement the provisions of the Biodiversity Act relating to prior informed consent and benefit sharing

1. Community Agro-biodiversity Centre: An institutional framework for achieving sustainable genetic resource management and livelihoods

Prof. M. S. Swaminathan's vision of integrating conservation, cultivation, consumption and commerce – a 4C approach to sustainable genetic resource management and livelihoods – has been evolved into a practical approach by establishing a Community Agro-biodiversity Centre (CAbC). The centre was established in 1997 in Kalpetta, Wayanad district, Kerala. The area is part of the Western Ghats, one of the mega biodiversity hotspots in the world as well as the tribal dominated district in the state.

The centre made an attempt to evolve methodologies to conserve genetic resources through an integrated approach of on-farm and ex-situ conservation methods. 10-12 seed villages are in operation to maintain the diversity of traditional rice varieties. The centre maintains a Botanical Garden in about 10 acres of land that houses over 2000 plant species of conservation and use value, and germplasm of many varieties of food plants like roots and tubers, legumes, citrus, wild edible greens and medicinal plants. The garden, along with its farmer partners, engages in collection and conservation of over 200 traditionally cultivated crop varieties, mostly food crops; more than 200 Rare, Endangered and Threatened (RET) plant species, over 600 species of ethno-medicinal plants and many other little known species. In recognition of the achievements in community biodiversity conservation programmes, in 2011 CAbC became the first member organization from India to join the International Partnership for Satoyama Initiative, a programme jointly launched by the Ministry of the Environment of Japan and the United Nations University Institute of Advanced Studies. In 2013, MSSRF joined International Union for Conservation of Nature as a member organization with two of its major regional centres – CAbC and the Biju Patnaik Centre for Medicinal Plants.

2. Developing a botanical garden for wild food and medicinal plants

The nearly two decades of MSSRF's CAbC resulted in collection and ex-situ conservation of over 200 traditionally cultivated crop varieties (mostly food crops), more than 200 RET plant species, and over 600 species of medicinal plants. These collections, sourced from on-farm, wilderness and forests, were later brought together in the M.S.Swaminathan Botanical Garden with distinct components for agro-biodiversity, medicinal plants, RET species of trees and so on. The garden is being developed further with the help of the Denver Botanical Gardens, USA with the core objective of promoting integrated biodiversity conservation and dissemination of scientifically credible knowledge in understanding the role and functions of biodiversity in enhancing climate resilience and nutrition. The garden has a conservatory for RET plants, a garden for crop wild relatives and rare varieties, a sensory garden, a children's garden and a butterfly garden. The garden has been envisaged to promote climate-smart biodiversity conservation and cultivation methods by linking the field gene banks, sacred groves, and the protected areas in the bio-valley of the Western Ghats..

3. Tribal Agro-biodiversity Centre: An institutional framework to promote tribal agricultural heritage

The Biju Patnaik Tribal Agro-biodiversity Centre at Jeypore in Koraput district of Odisha is located in the Eastern Ghat Highlands Zone. The district is known for its ecological wealth and is considered as a centre for secondary origin of rice. But it has the dubious distinction of being known for its poverty and hunger, thus presenting a paradox of genetic prosperity and economic poverty. The centre started its work in 1994 and subsequently, in 2006, it received the support of the Government of Odisha to strengthen its focus on agro-biodiversity management. The centre has also established an ethno-medicinal plant species garden with higher proportion of RET species based on the conservation traditions of nine tribal communities living in the region, namely *Bonda, Soura, Koya, Gond, Paroja, Gadaba, Bhumia, Bhatra* and *Kandha.*

Biodiversity conservation, sustainable agriculture and tribal livelihood: The agro-biodiversity of the region is fast declining due to various reasons. The explorative survey conducted by MSSRF during 1995-96 could collect only 324 landraces in the area. Currently the centre maintains

141 landraces of rice. Apart from rice, the centre has 31 accessions in small millets, 9 in pulses, 27 in vegetables and 46 in yams and tubers. Participatory varietal selection was carried out among landraces, of which cultivation of kalajeera, a non-basmati scented long-duration landrace, was preferred by the farmers. Subsequently, to enhance productivity while maintaining its purity, pure line selection was done. As part of the initiative, 32 landraces of rice were submitted to Protection of Plant Varieties and Farmers' Rights Authority for registration as Farmers' Variety. In compliance with the Convention on Biological Diversity norms, 17 People's Biodiversity Registers have been prepared in 17 gram panchayats of Koraput district and 32 Biodiversity Management Committees (BMC), comprising 224 members have been formed in these villages.

Globally Important Agricultural Heritage System (GIAHS): The traditional farming systems of Koraput was recognized as a GIAHS by FAO in 2012 for the efforts of the community to ensure biodiversity conservation, food security and preserving the traditional wisdom and cultural diversity of the region for the benefit of present and future generations.

Biodiversity mapping in Eastern Ghats: A holistic quantitative assessment of the geographic distribution and mapping of plant resources of the Eastern Ghats was carried out in Odisha state. During the assessment process, 585 plant species were recorded. Of these 163 are trees, 138 are shrubs, 174 are herbs, 66 are climbers and 44 are ferns, grasses, orchids and others. Three RET species, namely *Gnetumula* sp, *Albizia thompsonii*, and *Stemona tuberosa,* and three endemic species, namely *Selaginella nairii, Stemona tuberose* and *Themeda saxicola* were recorded.

4. Transforming millets from neglected coarse cereals to smart nutri-cereals

Kolli Hills, one of the tribal dominated blocks in Namakkal district, Tamil Nadu, is known for diversity in small millets. Five species, namely Little Millet, Foxtail Millet, Finger Millet, Kodo Millet and Proso Millet, are cultivated in this region. The 4C approach of conservation, cultivation, consumption and commerce were adopted to restore the cultivation of small millet species.

As part of millet promotional initiatives, A number of innovative interventions have been adopted to revitalize the millet cultivation in the tribal area which include identification of custodian growers, assessment of traditional knowledge, collection, characterization and evaluation of landraces, multiplication of high quality seeds, seed exchange system through community seed banks, introduction and dissemination of best cultivation practices, provision of low cost on-farm and post harvest processing machineries, enhance capacities of communities in value addition, develop new products and brands owned by communities, strengthen community-based institutions and effectively link the local millet products to urban, semi-urban and local markets.

Conserving millet landraces on-farm: The genetic diversity of different small millet species and their landraces was studied to design on-farm conservation strategies. At the same time, to strengthen its cultivation, horizontal networks among farmers were revived and since 2001, tribal farmers have been conserving 21 landraces of five millet species along with other associated crops through a network of 15 community seed banks that are functioning in seven panchayats in Kolli Hills. Over the period, about 17.10 metric tons of quality local millets seeds are being distributed through community seed banks for needed farmers that contributed to reach more number of farmers to cultivate millets across the region.

Promoting organized cultivation: As part of the promotion of sustainable productivity enhancement of millets and associated local crops, vermi-compost production is encouraged as value added organic manure. So far, about 84.92 metric tons of vermi compost were produced by 87 tribal farmers during last 6 years and applied for millet and other associated crops on their own farm. To enhance productivity in the available area of land, appropriate technologies and tools like line sowing, intercropping, weed management with the use of Cono-weeder and production and application of organic and bio inputs for millets have been evolved in partnership with tribal men and women farmers. Introduction of these

farmers friendly on-farm and post harvest machines have reduced about 75% to 90% of drudgery in these activities and productivity in millets has increased by 24% and net income by about 37% by applying improved agronomic practices.

Sustainable consumption and commerce: The introduction of milling facility in the area to process small millets created a major change in the outlook of women and substantially contributed to the revival of interest in millet cultivation and consumption. Currently 13 pulverizers and de-hulling mills are functioning across Kolli Hills. This reduced the drudgery of women in post-harvest processing and increased household consumption of millets and also contributed to millet value chain. Small-holding tribal farmers were collectivized as the Kolli Hills Agro-biodiversity Conservers' Federation (KHABCOFED) in 2009 with a membership of 1, 651 tribal men (1060) and women (591) farmers and a Farmers Producer Company in the name of Kolli Hills Agri-Bioresource Producer Company Limited (KHABPCOL) in 2016 with a membership of 583 tribal men (450) and women (133) farmers. As of now, there are 11 products marketed in the name of *Kolli Hills Natural Foods* through 25 organic outlets across Tamil Nadu. Over a period of eighteen years (2001- 2019), value addition, diversification and sale of products have generated a gross income of Rs. 74, 03, 156/- for those groups involved in value chain activities.

Chapter III

Biotechnological Tools for Improving Agriculture Productivity under Increasing Abiotic Stress

1. Novel genetic combinations of rice for salinity and drought tolerance

Agricultural productivity is majorly impacted by various abiotic stress factors, particularly salinity and drought in coastal areas. The Plant Molecular Biology group, in the initial stages, used various molecular markers to assess mangrove diversity both at intra- and inter-population and species levels, to complement mangrove restoration efforts taken up by MSSRF. This resulted in the first published reports on molecular phylogeny of mangroves and also highlighted, using marker-based tools, the existence of hybrid mangrove species in naturally occurring mangrove regions.

Based on the above analysis, halophytic species with natural tolerance to salinity as well as species tolerant to drought (*Avicennia marina*, *Oryza coarctata, Sesuvium portulacastrum, Suaeda maritima, Prosopis juliflora, Chrysopogon zizanioides* and *Macrotyloma uniflorum*) were selected to isolate and characterise genes conferring these traits. The genes associated with salinity tolerance were isolated using methodologies such as Expressed Sequence Tags (EST) and Next Generation Sequencing (NGS). These have provided extremely detailed snapshots of tissue specific gene expression under a given abiotic stress, with clues to the functioning of these genes. *AmSOD1* gene, encoding a cytosolic copper zinc superoxide

dismutase, was isolated from the mangrove species *A. marina* and introduced into rice using transgenic technology. These transgenic plants were tolerant to a salinity of 150 mM NaCl in both greenhouse and limited field trials conducted with approval of the Review Committee on Genetic Manipulation (RCGM). Transgenic plants were also tolerant to drought stress conditions. Transgenics carrying the *AmSOD1* gene were introgressed into locally-adapted rice varieties (IR 20, ADT 43, IR 60 and Ponni) using plant breeding technologies.

Backcrossed (BC4F1) plants were analysed using Polymerase Chain Reaction (PCR) based methods for identification and selection of positive plants (with introduced *AmSOD1* gene). Homozygous plants have been identified and analysed for their morphological, molecular and physiological traits. Three limited field trials were also conducted with the approval of the regulatory authorities of the Government of India.

Assessment of salinity tolerance in traditional rice landraces: A collection of 44 saline tolerant rice landraces from coastal regions of India have been genotyped using molecular Short Tandem Repeats (SSR) markers (diversity analysis) and comparative physiological assessments of plant performance have been made at the seedling stage. These landraces will now be examined with regard to root traits under salinity in both greenhouse and field conditions to identify genotypes with optimal root architecture (under salinity) for rice breeding.

In addition, salinity tolerance mechanisms in halophytic wild rice *O. coarctata*, a mangrove associate found in the coastal regions of India and Bangladesh, are also being analysed. This plant has specialised structures and mechanisms to tolerate salinity. The leaves of *O. coarctata* secrete salt under salinity through specialized secretory hair-like structures and for the first time, gene expression data has been made available for this tissue, to understand mechanisms of salt secretion in this species. In addition, sodium/potassium transporter genes, involved in ion homoeostasis, are being examined using molecular, cell biological and electro physiological tools at MSSRF and the University of Tasmania (UTAS) in a collaborative project. The research also employs gene editing techniques such as Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) to enhance the performance of salinity tolerance genes under salinity stress. Bio-informatic tools are employed to mine large gene expression datasets and complement the molecular work being carried out. Using cutting edge biotechnological tools, the Plant Molecular Biology group aims to enhance the scientific knowledge base for suitable application in the areas of plant abiotic stress tolerance.

2. Bio-prospecting lichens for compounds of therapeutic importance

Lichen bio-prospecting is one of the current national priorities. Lichen (fungi forming symbiotic association with algae) are secondary metabolites which function as chemical defence against various biotic and abiotic stresses, namely, anti-bacterial, anti-desiccation, etc, enabling the lichen thallus to successfully survive and compete with organisms sharing the same niche. The tropical lichens are poorly bio-prospected for their potential bioactive compounds. In this backdrop, 89 lichen species were established at MSSRF for the biosynthesis of secondary compounds. Lichen species such as *Buellia subsororioides, Dirinaria applanata, Glyphis scyphulifera, Graphis inamoena, Parmotrema praesorediosum, Roccella montagnei, Trypethelium eluteriae* and *Usnea complanata* were some of the noteworthy cultures that yielded known

and novel secondary compounds with significant bioactivity. The secondary compounds were isolated, purified and characterised at the Indian Institute of Technology Madras (IITM). The culture of *T. eluteriae* biosynthesized a total of nine molecules of which two are novel, belonging to pharmaceutically important Trypethelones and Phenalenones. The molecule MSSRF/TE/04 showed an MIC of 12.5µg/ml against both laboratory and clinical isolates of *M. tuberculosis* as well as select human bacterial pathogens. Similarly, a few compounds also showed selective anti-cancer activity against three cancer cell lines – breast (MCF-7), lung (NCI H460), human glioma (U251) – and control cell lines (Hek293, HaCat).

MSSRF has characterised the Polyketide synthase (PKS) genes that are involved in the secondary compound production of *Dirinaria applanata, Roccella montagnei, Parmotrema reticulatum.* The PKS genes are fairly large with sizes ranging from 8-10 Kb and are iterative enzymes composed of eight different domains, whose combinations determine the chemical characteristics of the released polyketides. Similarly, using metagenomics, the hidden fungal species (microbiome) within the lichen thalli, specifically diversity and their seasonal variation, were characterized. Further, steps are underway to take the lead molecules towards drug discovery in association with National Institute for Research in Tuberculosis.

3. Plant growth promoting rhizobacteria: prospective microbes for sustainable agriculture

The beneficial microbes present in the rhizosphere that are enhancing plant growth are known as Plant Growth Promoting Rhizobacteria (PGPR). These microbes also protect the plants from harmful abiotic and biotic stresses. Thereby they improve agricultural productivity and reduce the application of inorganic fertilizers and pesticides. MSSRF screened the soils from agriculture and mangrove ecosystems for PGPRs and has established a microbial culture collection with 36,000 isolates. This culture collection includes several novel genera such as *Swaminathania salitolerans, Mangroveibacter plantisponsor* and *Salinicola rhizosphaerae* sp. nov. from the mangroves and *Ciceribacter lividus* from the chick pea rhizosphere. PGPR species belonging to bacterial genera Pseudomonas, Bacillus, Azospirrillum, Rhizobium and others were isolated from paddy, finger millet, pepper and were characterized for biofertilization (enhancing nutrient uptake) and biopesticidal (plant protection) activity. These strains exhibited antagonistic activity against blast pathogen *Magnaporthe grisea* (TN508), *Gaeumannomyces graminis* (DSM1463), wilt pathogen *Fusarium oxysporum* (DSM62297), *Rhizoctonia solani*, *Macrophomina phaseolina* (DSM3586), *Erwinia persicina* (HMGU155) and *Xanthomonas oryzae* in laboratory conditions.

As a next step, a novel concept on microbe mediated 'Bio-fertilization and Bio-irrigation' (a process where under drought conditions, a deep-rooted plant lifts water from the moist bottom soil layers to the dry topsoil along the water potential gradient and the shallow rooted plants benefit) was tested to enhance the production of pigeon pea (*Cajanus cajan*) and finger millet (*Eleusine coracana*) in intercropping systems. The field trials were conducted during the cropping seasons for over four consecutive years in Kolli Hills, Tamil Nadu. The arbuscular mycorrhizal fungi (AMF) and *Pseudomonas* sp. (MSSRF D41-PGPR) were added separately or in combination to both pigeon pea and finger millet. Transplanted pigeon peas raised in polybags showed significant yield compared with directly sown pigeon pea. The treatment plots with both bio-fertilizer applications showed increased grain yields in both crops (up to +128%) compared to single inoculation. The trial fields were healthy and devoid of any disease incidence. The bio-fertilizer treated finger millet and pigeon pea seeds exhibited significantly higher levels of germination, seedling vigour index, and enhanced shoot and root length compared to control seeds. Biofertilizers in combination with transplanting may offer an efficient cropping system of pigeon pea and finger millet because yields increase. Thus this can be considered a step towards sustainable agriculture for enhancing the yield in pigeon pea and finger millet without chemical inputs.

To take up the results among farmers, an intensive hands-on training on the technical know-how of biofertilizer production was imparted to two women self-help groups in Kannivadi. They currently supply their products to 3400 farmers for 22 crops covering 2800 hectares. Thus use of these bio-products can offer a sustainable solution to enhance crop yield and maintain soil health.

. Chapter IV

Ecotechnology for Promoting a Bio-Village Paradigm of Sustainable Human Development

With the support of Tata Trusts, a JRD Tata Ecotechnology Centre was established in 1998 to assist farm women and men to enhance productivity in perpetuity without ecological harm, leading to an evergreen revolution. Since most rural livelihoods relate to crop and animal husbandry, fisheries, agro-forestry and farm forestry, and agro-processing, priority in agro-based livelihoods has to be awarded for enhancing the productivity and profitability of the major farming systems of the village on an environmentally sustainable basis. The mission of the Centre is to develop appropriate actions to achieve the following four goals:

- Enhance the ecological foundations essential for sustainable agriculture, particularly soil, water and biodiversity

- Enhance productivity and reduce cost of production through higher factor productivity
- Examine opportunities for agro-processing and value addition to the biomass through ecoenterprises and strengthen the small holders' competitiveness to have sustainable livelihoods

1. Enhance ecological foundations: Bio-industrial watershed development[2] (BIWS)

MSSRF field tested and fine-tuned the BIWS concept in five different agro-ecosystems across the country on a micro watershed scale of 500 ha. The main components of the programme were the soil and water conservation initiatives, participatory technology development and diffusion to improve the agricultural productivity and diversification, promotion of value addition through micro-enterprises and market links managed by local community-based institutions.

At the overall level the BIWS model ensured access to small-scale irrigation facilities in 650 to 1080 ha in the watershed area which doubled the cropping intensity from 100% to 200%. The intervention resulted in diversification of farm income sources and value chain development which, in turn, resulted in stability in farm incomes and reduced vulnerability to the impacts of climate change. Large number of women farmers were mobilized to access productive resources and services and their active participation in community-based organization was enhanced.

Under natural resources, soil and water conservation measures, efficient water management including water harvesting and improved groundwater recharge were given attention in a comprehensive manner. The soil and water conservation interventions cover a wide range– renovation of tanks, supply channels, check dams, individual and community level farm ponds, percolation tanks, compartmental bunding, etc. These have secured irrigation facilities for 38% to 60% of farmers in the select watersheds. Production has stabilized in key crops such as paddy, groundnut and maize in Koraput, onion, pulses and paddy in Villupuram, paddy in Pudukottai, wheat in Hoshiarpur and millets and pulses in Narasinghpur sites, while productivity has increased substantially by a range of 18% to 24%. Site specific off-farm and non-farm livelihoods have been promoted: goat, dairy, backyard poultry, aggregation and value addition in cashew and tamarind, mushroom production, pappad making, artificial stone polishing, tailoring, etc. This

2 This concept seeks to "empower and enable farming communities to conserve and enhance their natural resource base at a watershed scale, while also integrating with markets so as to increase their food security, environmental quality and economic prosperity", was proposed in the early 2000s by Dr. J.S. Bali. The approach builds on the conventional system of watershed management through sustainable agricultural production, value addition and new markets with appropriate institutional support systems, owned and managed by the community. Later, Government of India also adopted the concept and rephrased the programme as Integrated Watershed Development.

was to diversify members' sources of income, moving farm workers from unskilled to skilled labour status as well as generating additional employment in the local area. Each member earned Rs 1000 to Rs 4500 per month an additional income from the enterprises and they have established more institutional linkages for sourcing inputs, market, credit and technology. Community-based institutions focussing on soil and water conservation to deal with common property resources as well as farmers' groups to facilitate the input and output level market links have been promoted. Around 5000 farmers (42% are women) were mobilized and organised into farmer-producer groups. The value addition and marketing at higher end of value chain initiatives have supported farmers to gain an additional income ranging from 8% to 25% in the case of delayed marketing while, in the case of direct marketing of aggregarted products, it is 18%. On the other hand, when the products are value added by the primary aggregators (in this case FPO) the profit rose to more than 180% to 195%.

2. Rice biopark to trigger paddy and prosperity to go together

There is a saying in Asia that "paddy and poverty go together". This is because the earning opportunity for rice farmers is less than for those engaged in plantation, horticulture and cash crop farming. The aim of the rice biopark is to reverse this perception and make paddy an instrument of multiple sources of income, particularly by utilizing the entire biomass, including straw, rice, husk and bran, for making into market driven products to help the small land-holding rice farming families to earn more income and to generate more jobs. With the support of the Ministry of External Affairs, Government of India, MSSRF established a rice biopark in Yazin, Nay Pyi Taw, Myanmar. The President of India, Shri Ram Nath Kovind, inaugurated the biopark on 12th December, 2018. Built in 2 acre area and operated jointly by MSSRF and the Department of Agricultural Research, Government of Myanmar, it has the following facilities: paddy straw processing, enriched cattle feed block preparation, paper production, husk processing and husk ash production, a modern rice mill, production of poultry and fish feed, Spirulina, compost and husk ash. Nine master trainers nominated by the Government of Myanmar were provided training in various aspects of rice biopark activity, including maintaining and managing the modern rice mill, cattle feed block and paper production from paddy straw, production of bio-fertilizers from husk ash, mushroom production using paddy straw, vermi composting from paddy biomass, Spirulina culture and azolla cultivation. These trainers in turn trained 325 farmers, including women and youth.

3. Biovillage: an impact pathway to achieve SDGs

The Biovillage concept originated from the recommendations of an interdisciplinary dialogue organized at MSSRF in 1991 and it was then designated as an instrument to achieve the Millennium Development Goals. The Biovillage idea offered a "solution designer approach" with participatory development of locally relevant technologies and bottom-up strategies for holistic village development through empowerment of men, women and youth to innovate and practice in-situ sustainable livelihood methods focusing on on-farm, off-farm and non-farm dimensions.

The first Bio Village Cluster was established in Pondicherry over a period of five years (1991-1996) with initial support from International Fund for Agricultural Development and later from United Nations Development Programme and the JRD Tata Trust. In 1999 a Biovillage Resource Centre (Bio Centre), backed by a few ICT-enabled satellite Village Knowledge Centres, was established in Pilliyarkuppam village in Pondicherry to coordinate the Biovillage development programme. The programme organized under the leadership of a forum of local champions called Bio Village Council (Inniyur Grama Sangham) brought out practical evidence on the multiple causes of hunger and demonstrated various income generation methods/ small businesses at on-farm, off-farm and non-farm levels. By 2005, the number of trained women members was increased to 4500 with 120 women emerging as role models for empowered villagers. Now there are over 3500 active women hailing from 60 villages. They have organized themselves into a Bio Village Council, Single Women Forum, and Farmers' Producer Organization. This Biovillage model has shown that knowledge, skills and managerial empowerment of the village men and women is the key to poverty eradication and to progress towards creating happy farm families. Over the years, the Biovillage has become a proven pathway for achieving sustainable human development.

Using the Biovillage toolkit, capacity-building programmes were organized for SHGs, farmers, youth groups, NGOs, and panchayat leaders on concurrently addressing issues relating to natural resources conservation and enhancement, and the generation of new market driven enterprises. The model has been replicated in parts of Sikkim in India, in Bangladesh and Africa under Millennium village programmes.

4. Ecofriendly technologies for off-farm and non-farm enterprises

Dwindling employment opportunities for small producers in rural areas are an important concern for livelihood in the rural economy, especially for women. Hence, there is an increasing push to diversify their livelihoods from primary agricultural sector to on-farm and non-farm based small and medium enterprises, which is the next important sector in providing rural employment especially among women at the collective level. Towards this end, eco-friendly technologies have been demystified and village level decentralized production models have been tested with women members. The major focus has been on production of biocontrol agents (biofungicides, biopesticides, biofertilizers and bionematicides), which are essential base material to promote sustainable agriculture practices such as trichogramma, trichoderma, pseudomonas, paeciliomyces, azosprillum, phosphobacteria, Nesolynx thymus, etc. In addition, a handmade paper production unit was established in order to effectively use agro-waste, as well as pulse processing, apiculture and silk reeling units for value addition at grassroots level. Need-based technical, financial and market linkages are promoted through organizing the communities into federations. Apart from this, scientific backyard based dairy, goatry and poultry enterprises have been promoted among women members with centralized services for feed and disease management and collective milk marketing. The main impacts are: (i) about 11000 members have been involved in such science and technology based ecoenterprises which were institutionalized through grassroots institutions for support services, especially credit and marketing support; and (ii) transformatory changes in gender relationships have been observed at the individual, household and society levels interms of asset ownership, leadership skills, knowledge and skill, institutional linkages and recognition at household and community level. .

5. Farmer Producer Organizations (FPOs) to enhance small farmers' competitiveness

FPOs registered under the Farmer Producer Company's Act have been recognized as a competitive institutional framework to provide diverse services to small-holding farmers. The main objective of FPO promotion is to collectivize small producers, foster technology diffusion, enhance productivity, improve the access to inputs and output markets, market linkages and increase farmers' income by improving their participation in the value chain, thereby improving their on-farm livelihoods. MSSRF has been testing the model in eight different farmers' collectives across diverse agro-ecological systems in Tamil Nadu and Kerala with an average size of 750 to 1000 farmers per FPO.

The primary services offered by the FPOs are input and output marketing, acting as a resource centre to supply inputs, value addition to select crops, building the capacity of the farmers to improve their skills and knowledge, linkages to credit, seed production, farm machinery services and natural resources management. Of the services, value addition and market linkages are the crucial ones that shareholders accessed through collectives. In the initial year of formation, the FPOs are spending considerable amount of time and energy in organizing farmers, building their access to technology to improve productivity and venturing into collective purchase of inputs. Over a period of time, in the second and third years, the FPO takes up the services of aggregation and reduce the length of market channels. A few FPOs have engaged in delayed marketing wherever storage facility is accessible and taken up seed production. FPOs functioning for over three years are confident enough to enter into value addition initiatives by building their own assets for the processing units.

Observations from our work indicate that the FPOs' intervention in the market helps to bypass market intermediaries at one or two levels and directly forge a link with processing firms in the case of pulses, groundnut, maize, paddy and cotton in the Southern States and with retailers in vegetables. Apart from this, a few companies are involved in value addition to primary products (paddy, millets, pulses, coffee, cold-pressed oil, etc) and in directly reaching the consumers. Highly fluctuating prices in the market, lack of sufficient working capital, lack of sufficient storage systems and poor access to market intelligence make the FPOs sell immediately after harvest. Despite this, a few FPOs tried the approach of delayed marketing by storing products in storage godowns (wherever such a facility is available) and had a mixed experience of price flucatuations. For output market services, the average increase in price ranges between 8% and 25% in case of delayed marketing while, in case of direct marketing of aggregarted products, it is 18%. On the other hand, when the products are value added by the primary aggregators (in this case FPOs) the profit is more than 180% to 195%. However, with this range of profits, achieving the breakeven point by an FPO is still challenging irrespective of its period of establishment. The hands-on experience was shared with Tamil Nadu Small Farmers Agribusiness Consortium for evolving an apex body for the FPOs at the state level and contributed to the development of an exclusive FPO policy for the state of Tamil Nadu.

Chapter V

Food and Nutrition Security

In the early years, the Foundation led a Hunger Free Area Programme in Tamil Nadu and piloted a programme to address hidden hunger through horticultural remedies. The Food Security programme was established as a separate thematic area in the year 2004, under the aegis of the B V Rao Centre for Sustainable Food Security and the Ford Foundation Chair for Women and Sustainable Food Security . Subsequently, in line with work undertaken and the larger SDG goals, it has been renamed Agriculture Nutrition and Health programme. Work under this umbrella encompasses initiatives towards ensuring food and nutrition security of marginalized sections, through promotion of community food grain banks to address transient hunger, a farming system for nutrition approach to address malnutrition, building community capacity, mapping food insecurity, undertaking policy analysis, and advocacy for change.

1. Mapping food and nutrition insecurity

To understand the macro perspective of the country's food security concerns the foundation has prepared, between 2001 and 2010, a series of food insecurity reports in partnership with the UN World Food

Programme (WFP) in India. It comprehensively covered the three major dimensions, namely food availability, food access and food absorption, in rural and urban areas of the major States of India and in the country as a whole. The first in the series, the Food Insecurity Atlas of Rural India was released by the then Prime Minister of India, Shri. Atal Bihari Vajpayee in 2001 at a national consultation organized in partnership with the Planning Commission, Government of India. The Food Insecurity Atlas of Urban India published in 2002 was released by the then President of India, Shri APJ Abdul Kalaam. Subsequently, an Atlas of Sustainability of Food Security was published in 2003. These reports formed the basis for a major advocacy campaign in 2005-06–Mission 2007: Hunger Free India in partnership with WFP India and the National Commission for Farmers, Government of India. Following a similar approach, State level reports on food insecurity were prepared for the States of Madhya Pradesh, Odisha, Jammu & Kashmir, Rajasthan and Maharashtra. At the request of WFP Cambodia, a Food Security Atlas of Cambodia was also prepared.

2. Farming System for Nutrition: a pathway to zero hunger

Farming System for Nutrition (FSN), a farmer-led strategy, is defined by M S Swaminathan as: "The introduction of agricultural remedies to the nutritional maladies prevailing in an area, through mainstreaming nutritional criteria in the selection of the components of a farming system involving crops, farm animals and wherever feasible, fish". It becomes an important pathway of nutrition-sensitive agriculture in a context where agriculture is characterized by small land holdings.

MSSRF led a study from 2013 to 2017, to operationalize the concept of FSN to address undernutrition, in a cluster of villages in Koraput, Odisha and Wardha, Maharashtra, under a research programme on Leveraging Agriculture for Nutrition in South Asia (LANSA). The baseline survey revealed prevalence of high levels of undernutrition and largely cereal dominated diets. Both regions are characterized by small and marginal land holdings and rainfed farming. Widening on-farm crop diversity with nutrient dense crops like millets and pulses and nutrition gardens of fruits and vegetables on homestead lands were the main interventions, with fishery in Koraput and poultry in Wardha as animal husbandry interventions. The endline survey in 2017 revealed that, with the introduction of improved varieties and crops in the existing cropping systems and improved agronomic practices, the cropping intensity and food production at the farm level increased in both the study areas. The study also indicated that, 94% of targeted households in the study villages had greater understanding of nutrition-sensitive agriculture and a total of 69% of targeted households adopted at least one activity or more than one activity (crop/nutrition garden/fishery/poultry)

in their farms. The increased food grain availability and diversity at farm level and vegetables in nutrition gardens led to improved household dietary diversity as evidenced in increased number of food groups in the diet, consumption of all three groups of vegetables, increased frequency of consumption and increased average intake of the food consumed.

Advocacy for the FSN approach with policy makers led to support for 'nutrition-sensitive agriculture intervention' in the agriculture budget of Odisha for 2018-19. Following a meeting on Leveraging Agriculture for Nutrition with NITI Aayog in early 2018, the latter recommended that Indian Council for Agricultural Research take the lead in promoting the FSN approach through Krishi Vigyan Kendras (KVKs) across the country. Currently, FSN models are being promoted in KVKs in Odisha, Maharashtra and Andhra Pradesh, in collaboration with the agriculture universities in these states. The approach is being implemented in an entire gram panchayat in Koraput district of Odisha with support from the Rashtriya Krishi Vikas Yojana.

3. Community Hunger Fighters (CHF)

Community Hunger Fighters (CHF) is a learner-centred nutrition literacy approach undertaken in Koraput district of Odisha during 2012 – 2015. The study, used participatory action research methods, sought to facilitate a process of action and reflection by selected community representatives, both men and women, to help them identify, prioritize and take action, at least in areas under their control, to augment food and nutrition security at the household level. They were trained to address the issues related to importance of balanced diet and dietary diversity, food availability and sourcing of food, good dietary practices, food, nutrition and care during different stages in the life cycle, health care, livelihood and social health, in partnership with local institutions. The approach demonstrates that creation of intermediaries like CHFs at the village level helps to raise the community demand and bring synergy with local governance structures and government departments for convergence with different programmes.

4. *Mahila Kisan Sashaktikaran Pariyojana* for achieving social inclusion and gender equity

MSSRF initiated the Mahila Kisan Sashaktikaran Pariyojana (MKSP) in Vidharba region of Maharashtra to address the deepening agrarian crisis since 2007. Subsequently, in 2010, it was declared as sub programme of the National Rural Livelihoods Mission by the Government of India with budgetary allocation of Rs.100 crores. Between 2009 and 2017, MSSRF organised 3265 women farmers from 60 villages across three blocks in the districts of Wardha and Yavatmal in Maharashtra. One of the important outcomes of this programme is the improvement in the self-confidence and self-esteem of women, several of whom are widows of male farmers who committed suicide. Women farmers actively participated in gram sabhas and raised pertinent village specific socio-economic issues relating to drinking water, toilets, bus transportation, brewing of liquor, domestic violence, employment in the Mahatma Gandhi National Rural Employment Guarantee Scheme and Aadhar card. With reference to adoption of technologies, while just about one-fourth of women farmers adopted mixed cropping practices in 2013–2014, the adoption rate tripled by 2016–2017, when nearly three-fourth of women farmers had adopted this practice. Maharashtra State Rural Livelihood Mission identified 21 farmers as state resource persons to train other farmers in the adjoining villages on sustainable agriculture practices.

Chapter VI

Village Knowledge Centres: the building block for community empowerment

1. Knowledge centres for empowering communities: improving access to relevant ICTs

From 1992 to 2003, MSSRF's Village Knowledge Centre (VKC) movement, using the hub and spokes model, developed the Village Resource and Knowledge Centres (VRC-VKC) in rural Puducherry and Tamil Nadu. It aimed at providing demand driven information and knowledge services to impact the lives and livelihoods of rural communities. The grassroots experience of the VRC-VKCs demonstrated that, in an enabling environment, rural India is capable of learning, adapting and mastering new technologies for livelihood development, irrespective of the level of academic knowledge. With the spread of VKCs across India between 1998 and 2003, the learnings from VKCs were again confirmed: access to relevant, demand-driven and on-time information increased income and reduced risks related to livelihood.

This led to the National Alliance for 'Mission 2007: Every Village a Knowledge Centre', called as

Grameen Gyan Abhiyaan (GGA) or Rural Knowledge Movement. It is amulti-stakeholder partnership,the GGA addressed knowledge gaps and bridged the digital divide by bringing in the knowledge infrastructure to support effective deployment and use of ICTs. The success of Mission 2007 led to the commitment made by the Government of India under the Bharat Nirman Common Service Centres programme. Moreover, the mission's success had a snowball effect in Bangladesh, Nepal, Sri Lanka, Latin America and Africa.

2. National Virtual Academy Fellows

In 2003, the National Virtual Academy (NVA) Fellowship programme, the first of its kind in India, was initiated. It was conceived by Prof. M. S. Swaminathan, as a means of recognition of exceptional and passionate torch bearers who have displayed indigenous knowledge and innovative thinking for building inclusive societies in India's villages. The NVA is considered a pillar of Gandhi's Gram Swaraj movement and described, by the late Dr. A P J Abdul Kalam as "celebrating India's rural core competency". With support from Tata Trusts, the Jamsetji Tata NVA for Rural Prosperity annually selects one female and one male, from among exceptional committed cadre of grassroots academicians possessing a wealth of pragmatic experience, knowledge and traditional wisdom on livelihoods, who undertake the knowledge and skill empowerment of rural communities. A fully developed NVA is the largest professional academy so far undertaken in India to bridge the urban-rural (access to information and gender) divide. It also represents the power of partnerships in the technological and skill empowerment of the rural poor. It acts as a powerful tool for achieving development in the areas of poverty, gender, justice, social equity and partnerships. In 2007, the Jamsetji Tata Training School (JTTS) was launched as part of the NVA, offering life-long opportunities for pioneering Fellows to strive at building the capacity of India's rural population in mobilizing the power of modern ICT for improving the quality of their life, across diverse thematic areas..

3. Rural librarians

In 2015, the JTTS aimed at scaling up the concept of VKCs in the public domain through public librarians. This new capacity-building initiative titled 'International Network of Emerging Library Innovators India' (INELI) and South Asia, aimed at strengthening the capacity of 63 (43 from India and 20 from South Asia) public librarians as community library innovators having the ability to passionately drive the transformation of their public libraries into lifelong learning centres.

The holistic programme is designed for the local context, specifically for public librarians to relate with community development to develop their knowledge, attitude, and skills for enhancing their inner leadership qualities through a variety of learning environments and networking events over a period of 20 months. The course work of 14 modules specifically engages the librarians in the area of delivering need-based services for improving overall community development. The course work is completed by both national and international face-to-face knowledge exchange programmes, to promote interactive learning and sharing of knowledge and ideas among the selected peers.

In this translation of lab to land, INELI paved the way for knowledge action to reposition and strengthen public libraries in India as community-led lifelong knowledge learning centres. The selected INELI innovators and experiential library professionals together are fostering and enhancing their own libraries by designing and creating innovative knowledge-based services for building sustainable vibrant community oriented libraries. Over three years, these librarians have provided more than 64 innovative outreach services for 1,58713 (M:88809 / F:69904) communities, across thematic areas of health, education, agriculture, climate action, women's empowerment, skill empowerment, disaster relief and services, employment opportunities, and micro-enterprises. These innovative services are aligned with India's national priorities and UN-SDGs.

4. Plant Clinics

Agriculture plays a pivotal role in India's economy. Over 58% of rural households depend on agriculture as their principal means of livelihood. Plant diseases and other pests cause 40% reduction in yield worldwide. Timely diagnosis of various problems such as pests, disease, and nutritional deficiency and appropriate recommendations to address such issues are necessary to minimize production losses. Plant Clinic is an innovative model developed by the Centre for Agriculture and Biosciences International (CABI) and has been piloted by MSSRF in Tamil Nadu and Maharashtra, since 2012. Plant Clinic provides diagnosis and advice on any problem related to insects, diseases and nutrient deficiency symptoms in any crop and, when farmers need additional help, plant doctors connect them with new knowledge resources.

Plant Clinic is a tablet-mediated extension system for small and marginal farmers, conducted in a common location in a village by trained plant doctors who are agricultural extension officers and progressive farmers, to diagnose pests and diseases of affected crops and provide appropriate recommendations to farmers adopting Integrated Pest Management practices. Such timely advice enables the farmer to reduce losses and increase crop yield. Tools including a tablet, microscope, magnifier, laptop, and a projector, make the Plant Clinic a mobile unit to cater to different villages.

MSSRF currently runs 40 Plant Clinics covering 125 villages in Tamil Nadu, Maharashtra, Odisha and Puducherry. It has trained 32 plant doctors including 11 women. So far, it has conducted 1908 Plant Clinic sessions, in which 40586 farmers including 4410 women participated and tested 25564 crop samples. The outcomes are: 65% of the farmers adopted the advisories; many farmers realised 12% to16% increase in productivity, reduction in production cost in the range of Rs. 450 to Rs. 1200/- per acre according to the crop, an additional income of Rs. 4000 to Rs. 9300 per acre depending on the crop.

Chapter VII

Awards and Accolades over the Years

The Foundation started with initial corpus support from the proceeds of the World Food Prize received by Professor M. S. Swaminathan in 1987. Other notable prizes awarded to him were the Honda Prize for Ecotechnology, 1991, Tyler Prize for Environmental Achievement 1991, UNEP Sasakawa Environment Prize, 1994, Volvo Environment Prize 1999 and the Indira Gandhi Prize for Peace, Disarmament and Development 1999. More recently, Professor Swaminathan was awarded the first World Agriculture Prize in 2018 by the Indian Council for Food and Agriculture.

As a Foundation committed to and working on the lines envisioned by Professor Swaminathan, its work in different areas has been recognised over the years through various awards. These are listed below in descending order of year of award.

2018

Social Development Award – 2017 under organization category to MSSRF Community Agro-biodiversity Centre, Wayanad by Department of Biotechnology, Ministry of Science & Technology, Government of India, New Delhi.

2015

Earth Care Award for 'developing an integrated mangrove - fishery farming system and enhancing access to livelihood opportunities in the Pichavaram region of Tamil Nadu' - instituted by JSW Foundation and Times of India, New Delhi.

Felicitation of work done under LANSA in the field of advancement of nutrition by **The Odisha Environment Congress**, Bhubaneswar.

Agriculture Leadership Award in recognition of "the inspiring efforts in utilizing modern science for agricultural and rural development and dissemination of technology to improve lives and livelihoods of tribal and rural communities, Agriculture Today, New Delhi

Bioindustrial Watershed project implemented by MSSRF recognised as **best practice under Saansad Adarsh Gram Yojana (SAGY)**, Ministry of Rural Development, Government of India, New Delhi.

2014

Second Prize for work on Community Managed Bioindustrial Watershed from The **Humanitarian Water & Food Award (WAF)**, **Copenhagen mBillionth Award South Asia** in the category of Agriculture and Ecology for 'Fisher Friend Mobile Application (FFMA)' from Digital Empowerment Foundation, New Delhi Fisher Friend Programme, shortlisted as Finalist in **Mobile for Good award**, Vodafone Foundation

2013

National Award for Women's Development through Application of Science & Technology (2011), Department of Science and Technology (DST), Government of India, New Delhi

2012

National Water Award for 2010 for Tolla Watershed, Koraput District, Odisha, Ministry of Water Resources, Government of India, New Delhi

National Groundwater Augmentation Award for Illupur Watershed, Pudukottai District, Tamil Nadu, Ministry of Water Resources, Government of India, New Delhi

Runner Up Award for Mobile based Innovative approach of reaching small holding farming community received under Rural Innovation Fund of NABARD

2011

The Manthan Award, National Virtual Academy for Rural Prosperity from Digital Empowerment Foundation, New Delhi in the category e-agriculture and livelihoods.

2010

Garden at MSSRF Community Agro-biodiversity Centre, Wayanad recognised as **Lead Garden for Rare, Endangered and Threatened (RET)** species by Ministry of Environment, Forests and Climate Change, Government of India, New Delhi

2008

Green Institution Award to MSSRF Community Agrobiodiversity Centre, Wayanad From Kerala State Biodiversity Board, Trivandrum.

Jawaharlal Nehru Award for Science Communication, The Indian Science Congress Association, Kolkata

2007

Panchabati Grama Unnayan Samiti (PGUS), grassroots institution promoted by MSSRF recognised with **Genome Saviour Award** by Protection of Plant Varieties & Farmers' Rights Authority (PPV&FRA), Government of India, New Delhi

Rio Tinto Alcan Prize for Sustainability grant for training. IUCN, Switzerland.

2002

Tribal communities of the Jeypore Tract of Odisha where MSSRF works, recognised With **Equator Initiative Award** New York.

2001

Stockholm Challenge Award for Information Village Project – under Global Village Category, Stockholm.

1999

Motorola Gold Award in recognition of reaching the unreached through the hub and spokes model of information village project

1996

Blue Planet Prize, The Asahi Glass Foundation, Japan

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