DEFORESTATION, CLIMATE CHANGE AND SUSTAINABLE NUTRITION SECURITY: A CASE STUDY OF INDIA

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Abstract. Wheat and rice are the most important crops from the point of view of maintaining a sustainable nutrition security system for India, a country whose population may reach one billion by the year 2000. The implications of climate change deriving from tropical deforestation, particularly as concerns temperature and precipitation, with reference to the yield of wheat and rice in different parts of India are hence being studied carefully. Any possible positive gain arising from increased CO_2 concentration is likely to be offset by the yield decline induced by higher temperature and shorter growing period.

1. Introduction

There is now a view that deforestation affects climate in two salient ways: disruption of rainfall regimes on a local or national basis (Meher-Homji, this volume; Salati and Nobre, this volume); and through contribution to the greenhouse effect. There are additional climate repercussions from tropical deforestation, e.g. shifts in albedo. In each of these areas there are many scientific uncertainties. But it is recognized that the following climate changes will be important for agriculture:

1. Increase in temperature.
2. Changes in precipitation and storm activity.
3. Widespread run off.
4. Reduction in fresh-water availability.
5. Adverse impact on coastal agriculture due to sea-water intrusion.

A question which merits detailed study and analysis is the potential impact of these changes on the nutrition security of population-rich but land-hungry countries such as India and China. Swaminathan (1987) has defined nutrition security as 'physical and economic access to balanced diets and safe drinking water to all children, women and men at all times'.

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TABLE I: Demand projections for various agricultural commodities in 2000 A.D.

Item	Unit	Domestic demand
Food grains	Million tonnes	225
Vegetable oil	Million tonnes	10.2
Sugar and gur	Million tonnes	29.9
Cotton	Million bales	17.2
Jute and mesta	Million bales	11.8
Tobacco (dry)	Thousand tonnes	590
Milk	Million tonnes	64.4
Eggs	Millions (number)	28 513
Meat	Million tonnes	2.11
Fish	Million tonnes	5.5

Source: Based on the Report of the National Commission on Agriculture (1975).

2. Projected Demand for Food Supplies

India's National Commission on Agriculture (1975) estimated population and food needs to the year 2000. Various estimates projected the population at between 830 and 1032 million, depending upon growth rate; from the present trend, it appears that India will have a population of nearly 1000 million people by 2000.* Accordingly, the demand for food and other commodities will be as presented in Table I.

The domestic food grain demand includes mostly wheat and rice. The production of food grain has increased from 130 million t in 1980–81 to 170 million t in 1989–90, for an annual rate of increase of 4 million t. In the 1990s the required annual rate of increase in food grain production will need to be 5.5 million t. Therefore, the country will have to produce much more food grain, and do it under much more difficult conditions of land and water availability plus expanding biotic and abiotic stresses.

3. Climate and Agricultural Production

Agriculture is primarily dependent upon natural resources including solar radiation, water availability, soils and temperature regimes. Enhancement in productivity is the result of human endeavour through improved crop varieties, soil fertility, land management, irrigation and plant protection measures. Some crops have become the major crops of a region because they have been adaptable to the growing conditions prevalent at a given point of time. However, in India there has been a significant change in the production pattern of major cereals in recent years. The changes have been induced either by a technological trigger (e.g., photo-insensitive varieties of wheat and rice), or a marketing trigger (e.g. assured and remunerative prices for soybean), or by both.

* The 1991 census has revealed a population figure of 844 million.

In 1950–51 rice and wheat accounted for 57% of total cereal production, but by 1985–86 rice and wheat constituted approximately 80% of total cereal production. Rice and wheat are the major cereals of the world. Therefore, any climatic change which influences these two crops will have a profound effect on both food and livelihood security because these two crops are not only the primary sources of food but also of employment for millions of farm men and women. However, on a regional basis some crops may be more important than others. For example, in the Nilgiri Hills in South India, potatoes continue to be a major crop. In western India, particularly Rajasthan and Gujarat, pearl millet is an important crop.

Drought, caused by inadequate precipitation, is the most important climatic aberration which has influenced agricultural production in the Indian sub-continent since the beginning of settled cultivation. There were several droughts before 1900 which caused famine conditions in different parts of the country. These led to the establishment of Famine Commissions which made several recommendations. Among the major recommendations was the creation of irrigation facilities. The records in this century show that 1918 was the worst drought year, affecting 73% of the geographical area of the country and causing a 34.4% reduction in food-grain production over the previous best year. Subsequently there were major droughts in 1965–66, 1972–73, 1979–80, 1982–83, 1986–87 and 1987–88. The last drought affected 57% of the geographical area but caused a reduction of only 9% in food-grain production over the previous best. Thanks to the increase in irrigated area and to the introduction of early-maturing crop varieties characterised by resilience with regard to sowing dates, the production in a drought year has increased consistently over time (Table II). Governments' efforts in 'drought proofing' chronically drought-prone areas have also included long-term measures in strengthening the ecological infrastructure essential for minimising the adverse impact of drought, such as promoting water harvesting and watershed management and tree planting.

Apart from drought, the other factors which influence production in India are cyclones, which cause harm to standing or ripening crops in coastal areas. As a result of deforestation in the Himalayas, there is soil erosion causing siltation of

TABLE II: Impact of drought on food-grain production in important drought years

Drought year	% of the country affected	% reduction in food-grain production over the previous peak year	Total food-grain production (million metric tonnes)	Import of food grains (million metric tonnes)
1918–19	73	32.3	–	–
1965–66	54	18.8	72.4	10.6
1972–73	43	7.7	97.0	3.6
1979–80	41	17.0	109.0	0
1982–83	37	3.7	128.4	0
1987–88	57	8.7	137.8	2.0

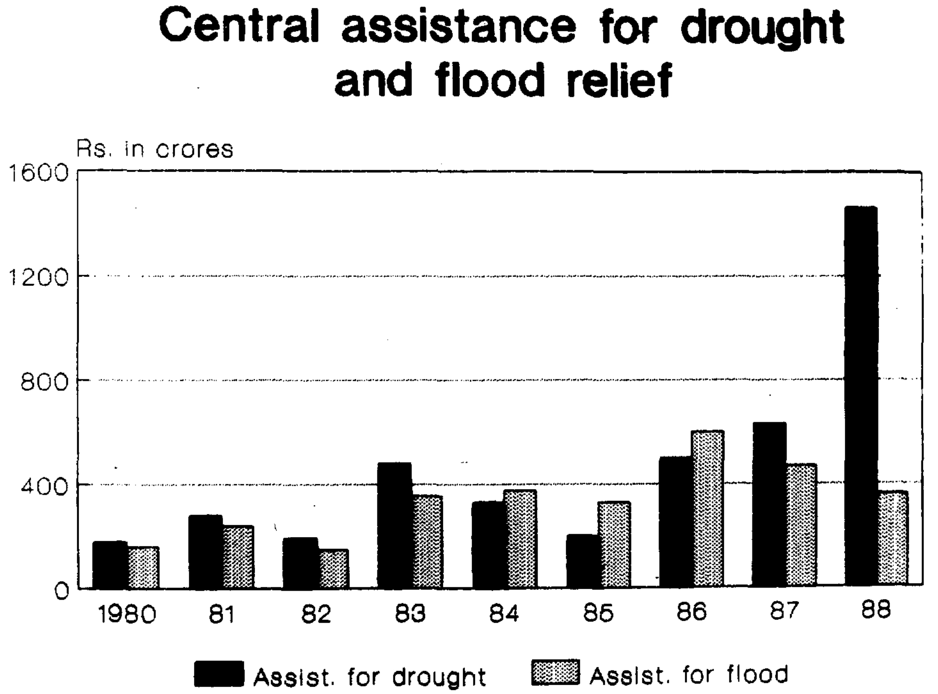

Fig. 1. Decadal means and standard deviations for All India Summer Monsoon Rainfall for the period 1871–1986. Source: India Meteorological Department, New Delhi.

rivers. This is reflected in the increasing incidences of floods. The assistance of the government of India for both drought and flood relief has been increasing in the 1980s (Figure 1). There is some damage through frost in north India, but its magnitude is very small in relation to total production.

4. Projected Changes in Climate for Tropical Regions and Their Potential Impact on Rice Production

Most predictions suggest there could be a rise in temperature of the order of 1.5–2.0 °C, and that this may be combined with uncertainty in precipitation. It is however, difficult to predict as to how a change of 1.5–2.0 °C would be distributed around the whole Indian subcontinent. For the sake of simplicity we can make an assumption that there could be a uniform rise in temperature throughout the subcontinent. Alternatively we can consider temperature changes in different regions as they occur based on mean temperature rise from one specific date to another (Figure 2). For example, there is normally a change of mean temperature of 1.7 °C from January 16 to February 1. The actual rise in different parts of the country ranges from 0.4 to 4.5 °C.

Rice is a major crop of the southwest monsoon season (June–October) in the Indian subcontinent and Southeast Asia. This period is characterised by high

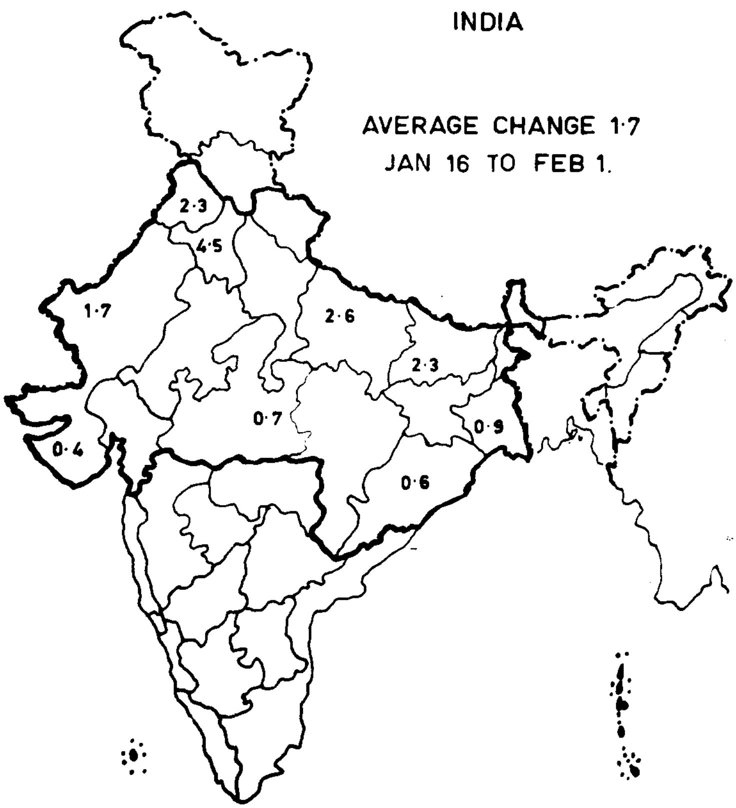

Fig. 2. Change in temperature in regions of India for an average increase of 1.7 °C from January 16 to February 1 in the regions delineated by thick lines.

humidity, cloudy weather and relatively high average temperature, being around 30 °C mean temperature or above. Both cloudy weather and high temperatures are not conducive for obtaining high yields. A study of yields in different parts of India shows that the average yield of rice in coastal regions is the lowest. Average yield increases towards the North-West region, being maximum in Punjab and Haryana (Figure 3). However, in the winter season when temperatures are mild in coastal areas such as Orissa, West Bengal and Andhra Pradesh, the yield of rice is better. That the rice yields are strongly influenced by temperature regimes has been brought out through the International Rice Testing Programme organized by the International Rice Research Institute. Increasing mean daily temperature results in decreasing the period from transplantation to maturity. Such a reduction in duration is often accompanied by decreasing crop yields (Figure 4). However, further analysis shows that the yield of rice is severely dependent on total radiation and minimum temperature from flowering to ripening (Table III).

Seshu and Cady (1984) have estimated a yield decrease of 0.71 t/ha with an

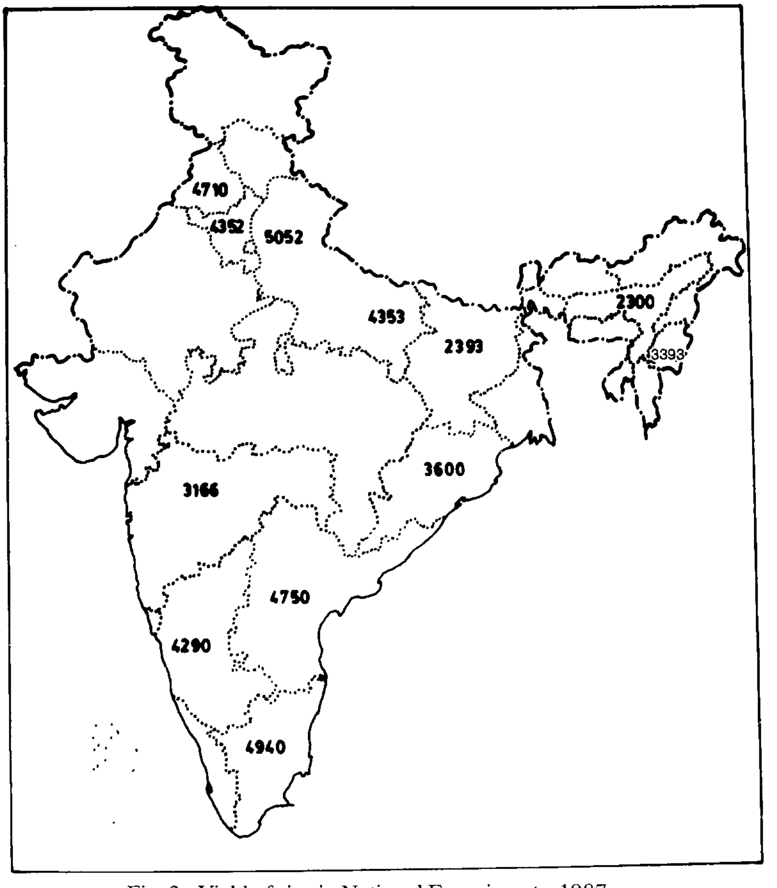

Fig. 3. Yield of rice in National Experiments, 1987.

increase in minimum temperature from 18 to 19 °C, a decrease of 0.41 t/ha from 22 to 23 °C, and 0.04 t/ha from 27 to 28 °C. There are several reasons for this variation in response to a 1 °C change in temperature at different temperature regimes. Among these are the effects of temperature on different phenological stages of plant growth particularly the sterility of the plant caused by higher temperature (Yoshida, 1981).

Several experiments in the past have shown that increasing levels of carbon dioxide could increase the photosynthesis rate and hence dry-matter production. Therefore an increase in carbon dioxide concentration might increase dry-matter production but due to increased temperature reduce crop duration and crop yield. Assuming that there would be an increase in temperature of 2 °C, there would be a decrease in yield of around 0.75 t/ha in the highest yielding areas of Punjab and Haryana; but the decrease in coastal areas, where monsoon season yields are poor, will be only 0.04–0.08 t/ha.

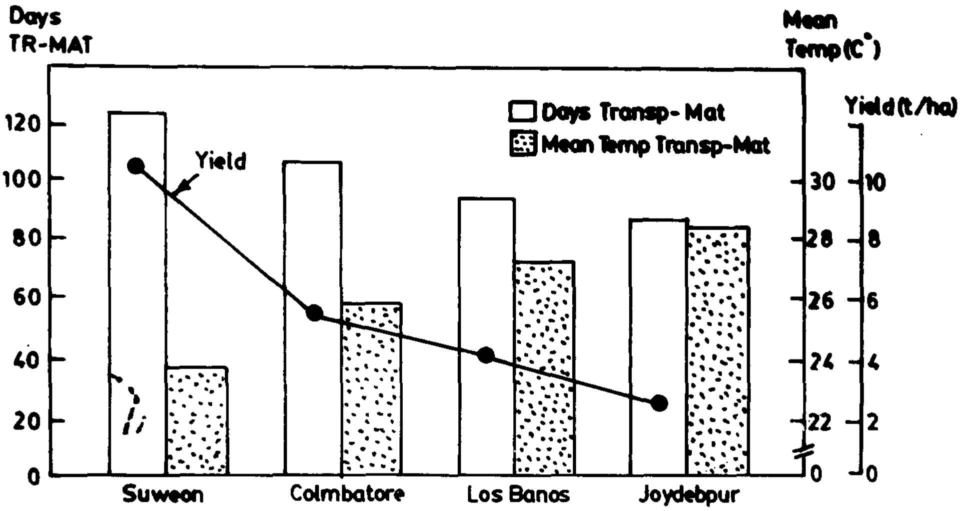

Fig. 4. Effect of mean temperature on growth duration and yield of rice variety IR36 at four sites, one each in Korea, India, Philippines and Bangladesh.
Source – International Rice Research Institute, Los Banos.

5. Impact on Wheat Productivity

Wheat is the major crop of the winter season in India and Pakistan. It has provided stability to cereal availability in India. Furthermore, the bulk of the grain buffer stock is of wheat, which is distributed through the public distribution system to exercise price control during climatically and agriculturally adverse periods. Therefore, any beneficial or adverse effect on the productivity of wheat will influence the national food security system.

Wheat is mostly grown in northern India between 22° N and 33° N, but a substantial area with low productivity exists between 11° N and 21° N. Experimental yields of wheat from the extreme north to south are given in Table IV, which clearly indicate that yields decrease from almost 5000 kg/ha to 1600 kg/ha from north to south. Two major factors – temperature and day length – are mainly responsible for this situation. Both the mean daily temperature and the photoperiod increase during the wheat season from north to south. If a wheat variety completes its growing season in 150 days in Punjab, it does so in 100 days or less in central or south India. A variety which completes its growing season requirement in a shorter duration becomes poorer in yield. Therefore any increase in temperature, even of the order of 1–2 °C, would result in adversely influencing the productivity of wheat. For each 0.5 °C increase in temperature, there could well be a reduction in crop duration of 7 days, which in turn would reduce yield by 0.45 t/ha. This means that an increase of 0.5 °C in mean temperature in Punjab, Haryana and Utta Pradesh

TABLE III: The effect of increasing minimum temperature on estimated rice yields. Model of Seshu and Cady (1984). Values in parenthesis are yield reductions

	Amritsar, India	Patna, India	Bhubaneswar India	Madras, India	Colombo, Sri Lanka
Latitude (°N)	31°38′	25°30′	20°14′	13°00′	06°42′
Elevation (m)	234	52	45	16	50
November harvest					
MINT[a] (°C)	15.6	22.1	23.3	25.1	23.8
Yield at current MINT (t/ha)	8.7	4.3	3.9	3.1	3.6
Yield at +1 °C temp. rise	7.8 (10)	3.9 (9)	3.5 (10)	2.9 (6)	3.3 (8)
December harvest					
MINT[a] (°C)	3.3	16.0	19.6	23.5	22.7
Yield at current MINT (t/ha)	*	8.2	5.6	3.3	4.0
Yield at +1 °C temp. rise	*	7.3 (11)	5.0 (11)	3.0 (9)	3.6 (10)
+2 °C	*	6.5 (21)	4.5 (20)	2.8 (15)	3.3 (18)
+3 °C	*	5.8 (29)	4.0 (29)	2.7 (18)	3.1 (23)

[a] Mean minimum temperature (MINT) during the month previous to the month of harvest.
* Temperature below the range of model validation.

would reduce productivity by 10%, while in central India, where productivity is relatively lower, the decrease may be still lower.

6. Summary and Conclusions

1. Deforestation has influenced the hydrology of the Himalayas, leading to de-

TABLE IV: Crop duration and grain yield of wheat at different locations

Location	Latitude (°N)	Duration (days)	Grain yield (q ha^{-1})
Gurdaspur	32	150	49
Ludhiana	31	148	50
Hissar	29	140	43
Pantnagar	29	140	43
New Delhi	28	140	43
Kanpur	26	137	40
Junagarh	21	125	35
Pune	18	120	31
Hyderabad	17	115	26
Bangalore	13	110	22
Coimbatore	11	100	16

Source: Based on several years data from the India coordinated project on wheat improvement. I.C.A.R., New Delhi.

creased flow in rivers and recession of glaciers. This causes more uneven flows throughout the year, and can also cause floods. Deforestation has also resulted in early siltation.

2. Though there is some evidence to show advantageous effects of the increasing levels of carbon dioxide in the atmosphere, particularly of 600 ppm, on crop plants, it may not be realised because of the adverse impact of increasing temperature.

3. In view of the fact that temperature rise would be caused partly by gases other than carbon dioxide, a study of the effects of the doubling of carbon dioxide on crop productivity alone would not be adequate. Consequently we should try to analyse the effects of increasing temperature and changes in precipitation patterns on various crops. These could be far more meaningful.

4. Since the increase in mean temperature has been described for grids by GCMs, it is essential that the mean temperature be distributed on a regional basis. The present trend of warming in India from January 16 to February 1, 1987, has been used for determining the distribution of the change in mean temperature over different regions of the country. An increase of 1.7 °C in mean temperature resulted in a variation from −0.6 to 4.5 °C in different parts of India.

5. If temperature changes occur as mentioned above, then some of the present-day productive areas may be affected adversely. Possible effects on rice and wheat have been described, but further studies are needed to evaluate the potential impact of precipitation and temperature changes on the major farming systems of each agro-climate zone. In India 15 major agro-climate zones have been recognized.

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