Global change scenario: Current and future with reference to land cover changes and sustainable agriculture – South and South-East Asian context

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Though the global change – change in land cover, land use, atmospheric concentration of greenhouse gases, loss of biodiversity and many related processes today–has enormous dimensions, this is the result of changes at micro-level, i.e. the village, small towns and higher order as a result of 'development'. Therefore, the corrective action or mitigation strategy should start at that level. There has been almost no change in forest cover in South and South-East Asia between 1978 and 1993. The important driving forces for land cover change are population, affluence and technology. While the developing countries have been attempting to define poverty, no effort has been made to define affluence, and also the responsibility of the affluent sections of the society towards local, regional and global change. The improved technology of crop production, particularly of wheat and rice, has resulted in saving 160 mha of land since 1961–62 in South and South-East Asia. New problems of sustainability of rice – wheat cropping system, groundwater pollution, reduced emphasis on nutritious grains (coarse grains) and stagnation in research on crop improvement have emerged. The regional cooperation and action points are suggested for meeting the new challenges.

NEARLY fifty years ago, I used to bicycle from my village to the District Headquarters, about 20 miles away. It hardly took a few minutes to get out of the mud houses (except three pucca houses) into the open fields and then into pasture land used for grazing as the village common property. The village common property area was more than the area of the village. On the way to the road, and passing through another village during the monsoon season there were several bushes which were covered by many cucurbits and at least three of them were edible as fruits or vegetables. Today, how I long to see that once again, but most of it is gone and there is hardly any common grazing land and the cattle freely roaming on that piece of land. Gone also are those bushes and cucurbits which we relished. One of them, kakoda, used as a vegetable, is no longer seen in the area – a loss of diversity for the region. Neither did I think those surroundings were gradually changing, nor had I a camera to record them or a perception of change. The population of the village which was around 1500 before 1950, could now boast of more than 4000 despite migration by many including myself to towns and big cities like Delhi.

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The village is now spread into almost three times of the area I had known as a child. The population has increased, a metal (pucca) road has come making it possible for buses to ply. There are mostly pucca houses for which bricks came from excavation of agricultural land. The ponds which once were filled with water during the monsoon and provided the fruits of *Trapa bispinosa* and fish, have dried, and for every 10 acres (4 hectare) or less of land there is a diesel pump to lift water, and many other changes have occurred. All this happened so gradually to meet the demands of increasing population and 'development' that one hardly saw what was coming. Now scientifically speaking, there has been a change in land cover and land use. I could also go back to my past and talk of disappearance of small forested land between villages and the pollution of the river Ganga which even today I revere because we jumped into its waters from the boat-bridge to swim everyday in the spring and summer during our examinations. I am now hesitant to enter the waters of the same Ganga at the same place.

Levels of land cover changes

The above description without going into details of changes in crops and cropping pattern at a village or microlevel provides the process of change in land cover. When taken for a group of villages it will represent changes at a higher level. If we add to this the components of energy, transport and other sectors, we would be addressing the problems of land cover changes at a higher order. These small instances bring out broadly the driving forces for land cover changes. In more specific terms, six components of driving force were identified[1], viz. population, level of affluence, technology, political economy, political structure, and attitudes and values. Though the last three are very important, it is difficult to develop indices to judge their impact. Therefore, a greater effort was put on population, affluence and technology. They were shown to have the following relationship.

Environmental change I = PAT, where P, A and T represent population, affluence and technology respectively. Several authors established a close relationship between population and environment[2,3]. However, it is difficult to identify thresholds of population and the environment in which population resides, because different environments would have different thresholds.

Affluence is considered a major factor for influencing the environment, both at the same location as well as elsewhere. For example if high-quality wood is needed by an affluent country, they buy it from some other country. Therefore, affluence could and does influence environment elsewhere, because of economic reasons. How do we define affluence? In developing countries there is a considerable debate including the international agencies for defining poverty. But possibly the question of affluence has hardly been addressed. The indices for affluence can possibly identify individuals and groups who should pay more attention to their responsibility to the society. In developing countries, a vast population has the primary need of meeting the food demand and therefore they spend 70% or more of their income on items of food. They hardly have money to acquire land for housing and living. But as their income increases, their expenditure on items of food declines and initially expenditure on clothing and housing increases. The expenditure on food articles in most of the developed countries may constitute only 10 to 20% or even less of the total income. Thus expenditure on food items, the area per person for living and expenditure on clothing, recreation and travel could constitute important indicators of affluence. When people spend more on food items, it also is an indication of low level of technology. Accordingly more and more land for agriculture is needed to meet the food demand. This is what happened everywhere in the world leading to deforestation. This happened in 18th and 19th Century in Europe and North America, but the same continued in 20th century, in Asia and Africa. The arrival and improvement in technology for food production changed this pattern. It is likely that technology helped arrest of deforestation in some regions, but it added to environmental problems in others. Since the focus of the present discussion is land cover change and sustainable agriculture, it is addressed to some extent.

Changes in forest cover

The changes in forest cover are important because it is generally felt that in early stages of development deforestation provided land for agriculture and wood for housing and fuel. Since deforestation has possibly contributed CO_2 to the atmosphere (by reducing the sequestering of CO_2 through photosynthesis, and loss of organic carbon from deforested soils), its role in global change has been emphasized. There are historical records to make both estimates and guesstimates for the land cover change involving forests. Richards and Flint[4] described change of land use in South and South-East Asia for the period between 1880 and 1980. There have been many changes in the boundaries of many countries in this region in the past 100 years. Therefore, it is difficult to be accurate in estimates but we have some numbers. However, from 1950 FAO records provide continuity till now though there are some earlier estimates also but they relate to only parts of this region. Richards and Flint[4] included three major categories of forests, viz. forest/woodland, interrupted woods and forested wetlands. The trend for deforestation for South and South-East countries is shown in Figure 1. According to these authors, the forested area in 1980 was 342.6 million hectare, but on the basis of FAO year books, the forested area in 1978 was 318.2 million hectare including that of Nepal and Pakistan which are not included by these authors. This creates a difference of 10% between 1980 and 1993, depending on which numbers we consider. In a period of 110 years

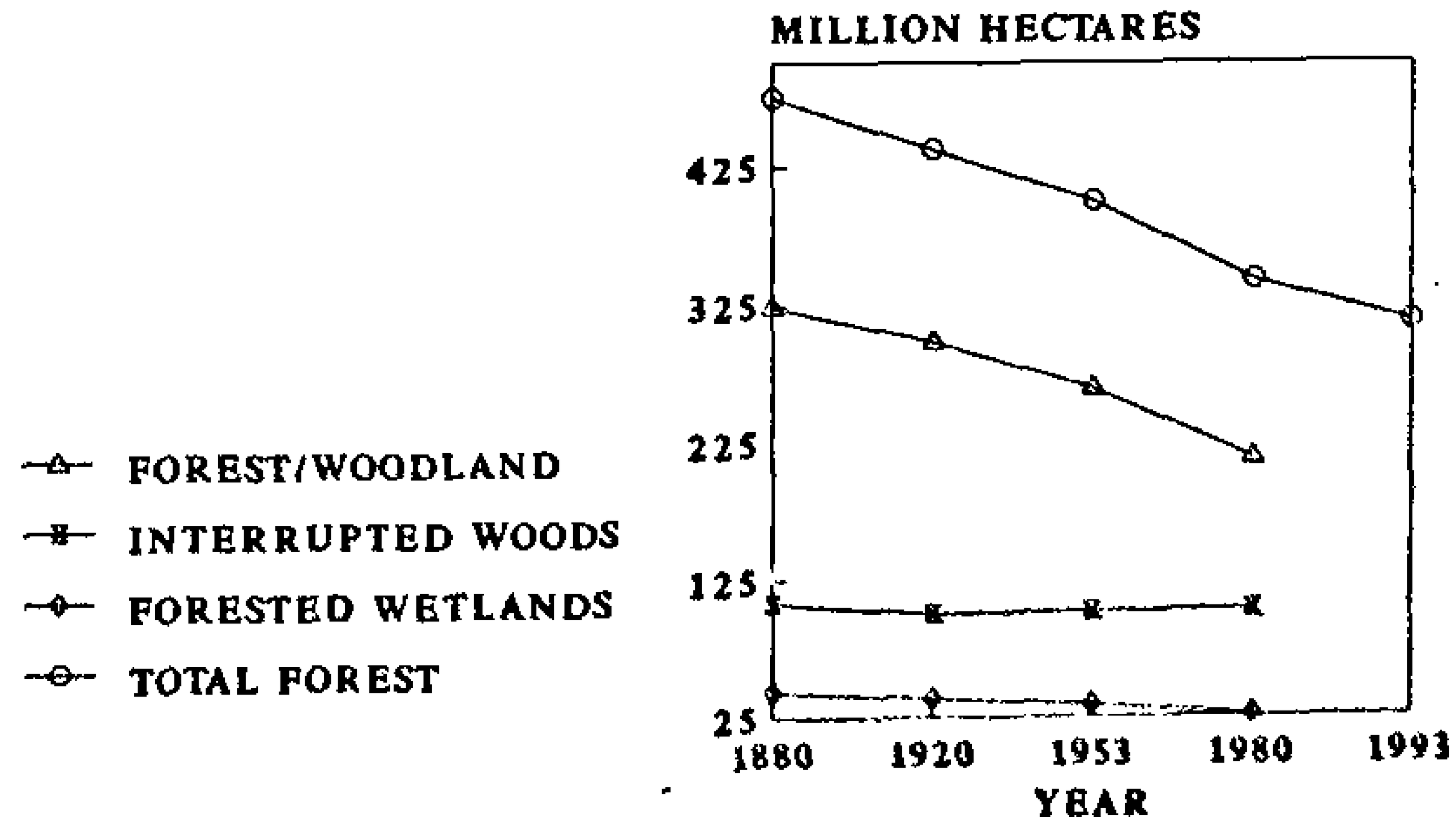

Figure 1. Change in forest cover in South and South-East Asia from 1880 to 1993 (million hectares).

the forested area decreased by 35% in South and South-East Asia. Though there are some estimates of contribution of CO_2 to the atmosphere, they have a large element of extrapolation, and sometimes from the non-representative regions.

It is much more important to analyse recent changes in the context of population growth and agriculture. Between 1978 and 1993, a 15-year period, there was a decrease of only 6.0 million hectare forested land being 1.88% of the 1978 forested area. In the meantime, the area under permanent crops such as coconut, oilpalm and rubber increased by 5.7 million hectare (Table 1). If we take these permanent crops as another kind of forest, then virtually there was no deforestation in the last 15 years. The situation in India is also contrary to a general belief. From 1980 till now there has been an increase in dense forest (forest/woodland) and hence in biomass (Table 2). It has been estimated that the carbon-pool in Indian forests increases annually by 8.5 to 12.5 million tons of carbon (TgC).

Thus, there is a need to make better estimates of forest cover and their potential for assimilating atmospheric carbon dioxide. It is possible that deforestation in South and South-East Asia has decreased substantially, and area of dense forests is increasing (Table 3). There are, however, only a few estimates of CO_2 emission from deforested soils. The long term database is required to establish more accurate trends. Some of the models used for this region should be validated and the inputs for different types of forests be improved.

Table 1. Changes in areas of forests and woodland and permanent crops in South and South-East Asia

	Million ha	
	Forests and woodlands	Permanent crops
1978	318.2	23.4
1993	312.2	29.1
	– 6.0	+ 5.7

Table 2a. Decrease in forests woodlands and interrupted forests in South and South-East Asia

Country	Million ha	Change over 1978 (%)
Bangladesh	0.25	13.4
Laos	1.4	10.0
Cambodia	1.58	12.0
Thailand	3.4	19.9
Vietnam	3.8	28.3
Indonesia	7.9	6.62

Based on *FAO Production Year Book*.

Table 2b. Increase in forests woodlands and interrupted forests in South and South East Asia

Country	Million ha	Change over 1978 (%)
Myanmar	0.24	0.73
Nepal	0.1	1.80
India	1.38	2.06
Malaysia	0.56	2.60
Philippines	0.74	5.7
Sri Lanka	0.32	18.0
Bhutan	0.52	20.0
Pakistan	0.71	25.6

Based on *FAO Production Year Book*.

Land cover changes and land-saving technology

Increase in population has an immediate effect on demand for food and housing. In the past 30 years, South and South-East Asian countries have been able to meet their food demand. Countries such as Thailand, Vietnam and to some extent India are emerging exporters of some agricultural commodities. This has occurred through both the increase in area under cultivation as well as increasing productivity of land. The forest cover decreased by 30 million hectare since 1961–63 in this region, and the area for cereal production increased by 30 million hectare. It does not mean that all land for cereal production came from deforestation. Even among cereals there has been a change in land use. For example, the area under coarse grains (including maize) decreased but increased for both rice and wheat. This change resulted in increased cereal production by 235 million tons, a significant part of it coming from the increased productivity. Broadly speaking, the new technology of rice-paddy and wheat production resulted in saving 160 million hectare land coming under cultivation (Table 4). This has often been called the land saving technology[5].

Sustainable agriculture

There are several perceptions of the agriculture and land cover change for South and South-East Asia. It is often

Table 3a. Change in forest area, phytomass C-pool and change in C-pool for the year 1982–1991 (India)

	1982	1991
Change in area (km^2)	24715.98 (dense)	– 25325 (open)
C-pool (mt)	3683–4268	3768–4381
Change in C-pool (mt)	76.27 (low)	113.18 (high)

Dadhwal and Shah[18].

Table 3b. Change in carbon-pool of forests in India

	Tg C (million ton C)
1982	3683–4268
1991	3759–4381
Change	76–113
Annual increase	8.5–12.5

assumed that deforestation has largely been for increasing area for agriculture for meeting the food needs of the growing population. There is a perception, not unjustifiably that agriculture in Asia is becoming unsustainable. Therefore, how would the future demands of food be met? Would there be further deforestation and degradation of natural resources? We first need to define sustainable agriculture, and then try to develop a perception for this region, because identification of problems is only an initial step towards solution which must be the priority now. Nevertheless, the following definitions or statements are important in understanding sustainability. Swaminathan[5] gave the relationship between productivity and other parameters by the equation

$$\text{Productivity} = \frac{\text{Output value}}{\text{Input value}} + \text{Change in environmental stock.}$$

Thus, the concept of various inputs and the value of environment was introduced. He implicitly means that productivity should add or improve the environment. Therefore, it becomes necessary to define environmental stock in terms of either ecology, economics or human well being. For example, the value of water, which is taken for granted, on the banks of big rivers or high rainfall areas may be insignificant, but the same acquires a high value in water-scarcity areas. Therefore, there is a need to put a value to environmental stocks. Maurice Strong[6] stated 'Sustainability means a transition to a wholly new system – one which will permit, in the case of agriculture food production to continue to rise to meet human needs without destroying the underlying basis for supply of nutrients, maintenance of soil conditions. Sustainability is not so hard to define in the field of agriculture as it is in some other fields.'

Kada[7] referred to a simple statement of Wendell Berry, 'A sustainable agriculture doesn't deplete soils or people'. Kada continued 'Over time, an increasing number of researches, farmers, policy makers and organizations worldwide have developed a definition that unifies many diverse elements into a widely adopted comprehensive working definition. Sustainable agriculture is ecologically sound, economically viable, socially just and humane.'

Table 4. Changes in production, area and rate of total cereals in South and South-East Asia

	Period		
	1961–63	1991–93	Change
Area (mha)	142.2	174.2	30.0
Productivity (mt)	167.2	392.1	234.9
Rate (kg/H)	1179	2251	1072

Additional land requirement 190.2 mha instead of 30.0 mha. Hence saving of 160.2 mha of land.

Thus, this definition identifies four main factors, but it is likely that in developing countries most of these require far greater clarification than simply abstract concepts.

The Bruntland Commission on Environment and Development Report on Our Common Future[8], defined sustainable development as the one to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.

Thus, the emphasis is on meeting the present needs from the natural resources without impairing them for the future generation. It is not possible to enlarge this discussion to cover many aspects of human development and welfare, but it is best to address a few examples which bring out the dilemma. It has been shown earlier that deforestation has been slowed down considerably in South and South-East Asia in the last 40 years. As stated earlier the decrease from 1978–79 to 1993 in forest area was 6.0 million hectare, 1.88% of the forest area. In the same period, the area under permanent crops increased by 5.7 million hectare. Assuming that the permanent crops such as coconut, oilpalm and rubber represent a different nature of forests, there is no deforestation in this region. More so because there has been no increase in area for food grains.

Rice-based cropping system

Asia as a whole is predominantly a rice producing and consuming region, with about 92% of the total rice production. In South and South-East Asia also, rice remains a major crop but wheat is important in India, Pakistan, Bangladesh and Nepal. These two crops have provided food security in the region. The future of food security of this region is also strongly linked with the sustainability of these crops which have started showing signs of stagnation and deceleration.

There was a very significant change in growth of cereal production from 1961 to 1993. The change in area under cereals grew at a simple growth rate of 0.88% annually but production went up from 167.7 million tons to 392.1 million tons from 1961–63 to 1991–93. This gave a growth rate of 4.46% which outstripped the population growth rate. The latter was 3.23% annually for the same period (Table 5). However, a detailed analysis shows that during the 30-year period, rice-paddy production increased by 4.07%, wheat 4.48%

Table 5. Simple annual growth rate of population and cereal production in South and South-East Asia

	Period		
	1961–73	1971–83	1981–93
Population	2.69	2.52	2.38
Cereal production	2.93	3.93	2.98

and other cereals 1.81%. Thus put together cereal production has remained high essentially because of rice and wheat. However, it is now clear that for this region the peak growth rate of rice was achieved between 1971–73 and 1981–83, but for wheat it was between 1961–63 and 1971–73. There has been a distinct decline in production growth rates in the decade of 80s. Therefore, some important questions are raised: (i) Would cereal production growth rate remain higher than population growth rate in the coming decades? (ii) While a decline in growth from the initial high is generally expected, would it remain around 3.0% in future also? (iii) What needs to be done to meet this objective?

Those questions can be analysed if not answered by considering sustainability of productivity and production at different levels. These are as follows: (i) Sustainability in large area such as South and South-East Asia, (ii) Sustainability in a country and within a country, (iii) Productivity potential through demonstrations, (iv) Sustainability on research farms – trends in improvement.

This analysis indicates that at the regional level, growth rates in the 80s in rice and 70s in wheat have not been maintained. There could be various reasons for this: (i) Initial high rates which are not sustainable because of limitations of biological system, (ii) Inputs have not matched the removal of nutrients, (iii) Socio-economic factors which effect growth.

The data on productivity of rice-paddy and wheat for the period between 1992 and 1994 clearly shows that there is almost no improvement in productivity in major producers of these cereals in South and South-East Asia (Table 6). Does it suggest that upper limit of productivity of these crops has been reached on a large area basis? Table 7 shows fertilizer consumption in some of the countries of Asia. Since this consumption does not pertain to rice, it is difficult to draw conclusions, but the experience shows that a large part of fertilizer is used for commercial crops, fruits and vegetable crops. Even so, it indicates a low level of consumption with a poor ratio of NPK. There is, of course, no mention of micronutrients. It is thus possible that stagnating yields are being caused by several factors, the imbalanced and low fertilizer use being an important one.

Table 6. Productivity (kg/ha) rice-paddy and wheat of major producers

	1992	1993	1994
Rice-paddy			
India	2618	2774	2817
Indonesia	4345	4375	4344
Bangladesh	2703	2678	2796
Vietnam	3334	3615	3462
Myanmar	2934	3055	2942
Philippines	2855	2955	3030
Wheat			
India	2394	2323	2420
Pakistan	1991	1947	1876
Bangladesh	1853	1846	1839

Rice–wheat rotation and rice–rice rotation

Rice–wheat rotation has emerged as an important cropping system in South and South-East Asia with a total area of 22.5 million ha, including China. The South Asian Countries – India, Pakistan, Bangladesh and Nepal together have 11.1 million ha where rice–wheat rotation is practised. The productivity of this system has been high and economically remunerative, therefore popular among farmers. However, there is a perception for the past few years that this system has become unsustainable. Consequently we need to ask the following questions: Is productivity of rice–wheat system declining, is it of rice or wheat? Is it true for the whole region or only of some parts? Is duration of rice crop a major factor for poor yield of wheat? Are there any soil, physical and biological factors which influence this rotation? Does this problem exist on research farms or in farmers fields? Are there any new pest problems – diseases, insects, nematodes, etc.? Is fertilizer and soil fertility management inadequate? Is water and water management a problem? Any other factor such as residue management and tillage? Will simulation models help?

Precise answers to these questions are difficult to find. A few years ago when work on this problem was initiated at Indian Agricultural Research Institute in 1992, three villages in Muradabad district of UP, about 160 km east of Delhi, were selected for the study. These three villages Nanhoowals, Hariana and Hamirpur have practised rice–wheat crop rotation for more than 20 years. These villages represent high, medium and low levels of productivity (Table 8). It appeared that the low-productivity village had a mild level of alkalinity and a low level of available phosphorus. Since the farmers are giving several irrigations to rice crop, it is likely that sodicity problems may arise in future. The physical properties of a 5-year and 15-year rice–wheat rotation systems at Karnal were also analysed. The hydraulic conductivity of the 15-year rotation was higher

Table 7. Fertilizer consumption of agricultural land in some countries of Asia (kg/ha)

	Period			
Country	N	P_2O_5	K_2O	Total
Bangladesh	71.5	14.5	6.1	92.1
India	48.5	14.7	5.0	68.2
Nepal	12.7	3.7	0.3	16.7
Pakistan	63.2	17.7	0.9	81.8
Philippines	38.2	9.2	5.9	53.3
Sri Lanka	49.0	16.4	24.4	89.8
Japan	117.1	142.1	95.4	354.6

FAO[19].

than 5-year rotation but is difficult to relate it to productivity. The biological activity, particularly microbial activity increased. The nature of microbes was not characterized. It is possible that the population of various kinds of microbes changes. Depending upon their chemical-producing ability these could be promotary or inhibitory to plant growth. This needs to be understood.

Changes in land use for crops in India

Significant changes in cropping pattern have occurred in India in the past four decades. In 1950–51, the coarse grains (maize, sorghum, pearl millet, minor millets, etc.) constituted 45% of the total cereal production coming from the area cultivated with cereals. Because of irrigation and other management factors a shift started among these crops by 1960. The maize crop experienced waterlogging in monsoon season in UP and Bihar and so did in Punjab. Consequently, rice which was not a crop of the region became a major cereal in monsoon season (Figures 2–4). Pearl millet or Bajra which occupied about 0.2 million hectare is almost non-existent in Punjab. As against this, rice is cultivated in 2 million hectare as opposed to its non-existence in 1960–61. Sorghum was a major cereal crop of Andhra Pradesh occupying more than 2.5 million hectare in 1970–71 but today it has come to 1.3 million ha. A major factor was the economics in farming. It has, however, resulted in changes which in the near future could lead to an adverse effect on production as well as human health. The changes in Punjab, an important grain-producing area, is described in some detail.

Table 8. Yield range of rice-paddy and wheat in the three villages of Muradabad District (UP)

	(Q/ha)		
Village	Rice-paddy	Wheat	Level of production
Nonhoowala	60–70	40–50	High
Hariana	35–50	35–40	Medium
Hamirpur	20–30	20–25	Low

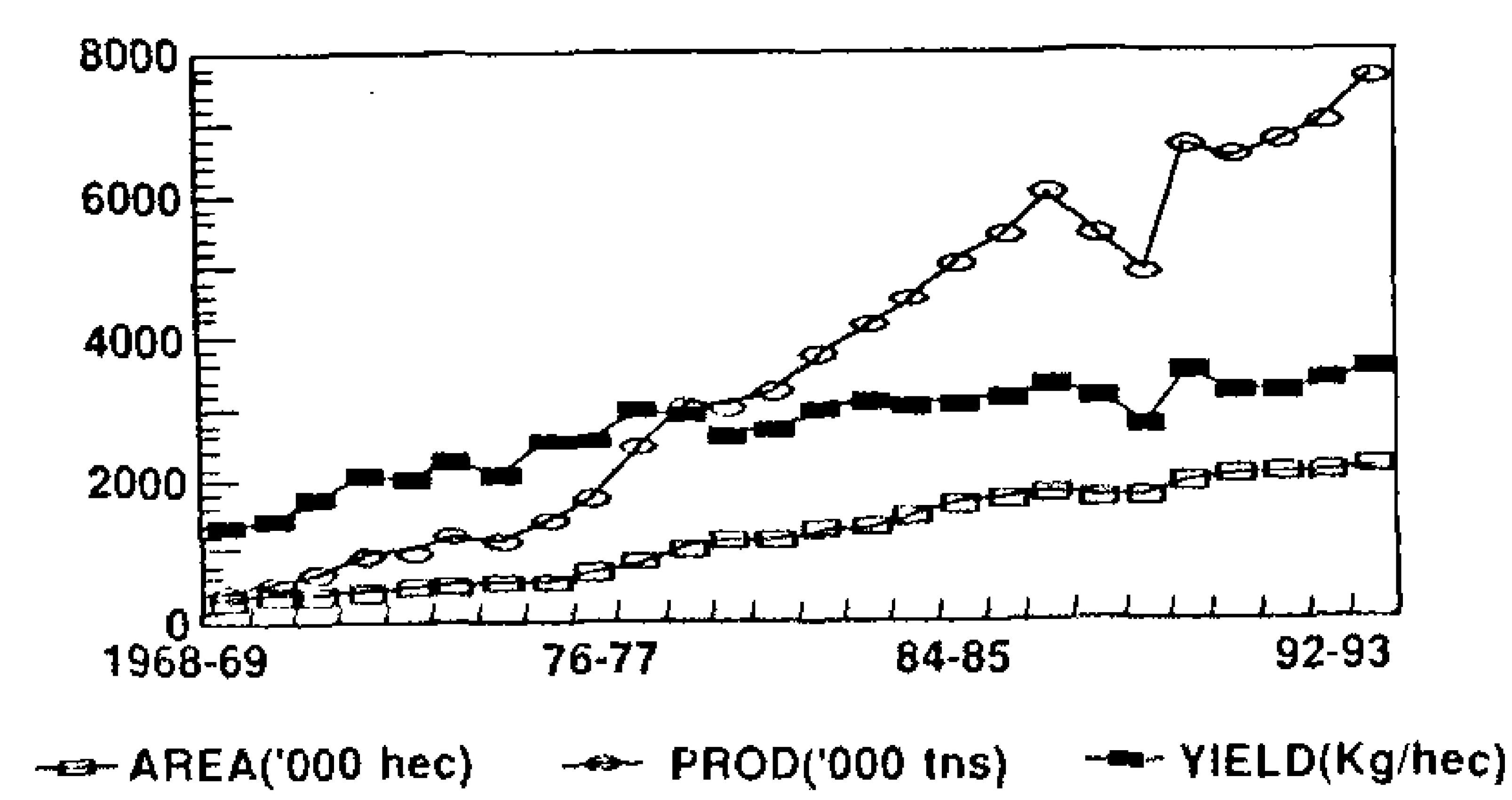

Figure 2. Change in land use pattern for rice in Punjab.

Prospects of rice–wheat production in Punjab

We identified Punjab, Haryana and UP as the key states for providing stability in production and for food security in the country[9]. In 1992, the Punjab contributed one-third of the production and two-thirds procurement of rice and wheat, among the key states. The sustainability of rice–wheat cropping system is a matter of concern for this region. Within Punjab, five districts, viz. Patiala, Jalandhar, Ludhiana, Sangrur and Amritsar had a growth rate ranging from 7 to 27% between 1971 and 1989. These districts contributed more than 60% rice and 50% wheat production. Since the market price was remunerative, the farmers were happy and so were bureaucrats and politicians, because this state became a model for agricultural development.

The consequences of high production of rice and wheat are no longer encouraging. There is stagnation or decline in area for wheat production (Figure 5) from 1984. The impact of increase in the area under rice on groundwater in five key districts of Punjab was analysed. It showed that area under rice increased at the rate of more than 10,000 ha annually since 1969 in all these districts, while the groundwater level in October (post-

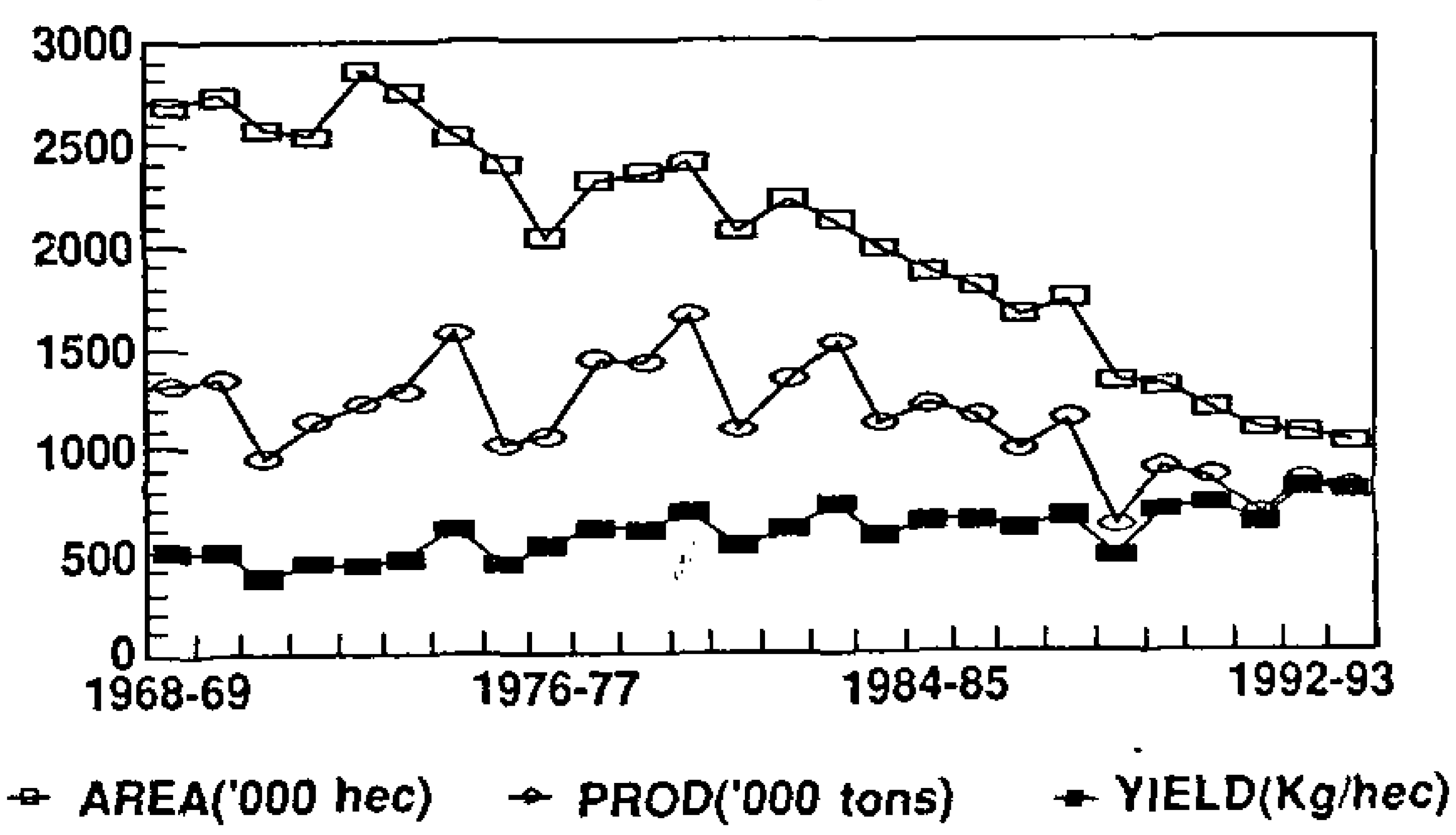

Figure 3. Change in land use pattern for sorghum in Andhra Pradesh.

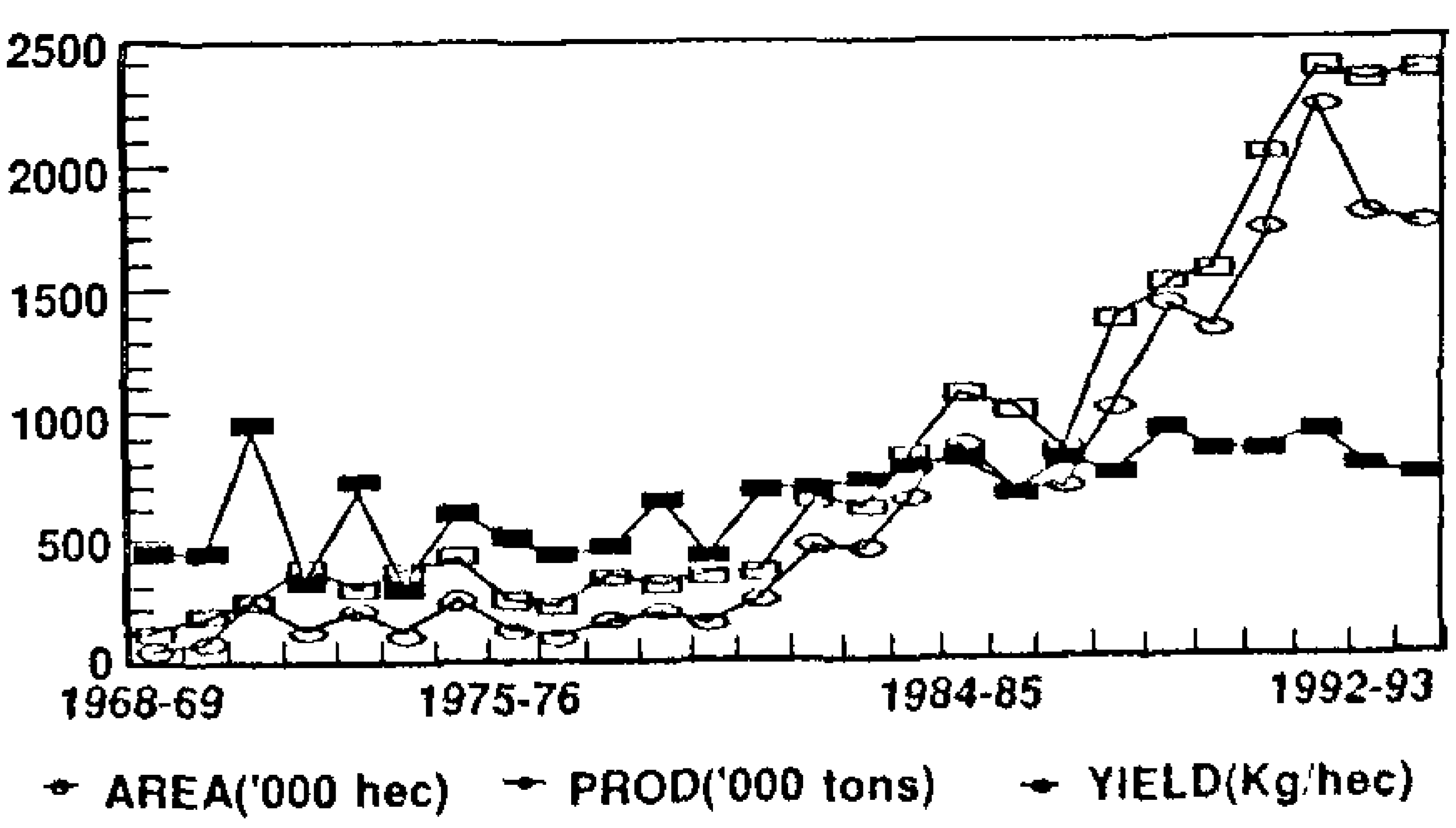

Figure 4. Change in land use pattern for rape seed and mustard in Rajasthan.

monsoon) has fallen at the rate of 0.17 to 0.46 in per annum (Figure 6). Thus in some of the districts the water level has gone down 3 m or more. This puts in a serious question on sustainability of rice production which is a major consumer of water. When there is success in an endeavour, the immediate gains make us forget the future of our coming generations. Farmers in Punjab and Haryana started planting rice in mid-summer, April and May to harvest two crops of rice. A high evaporative demand has brought the present situation which needs immediate attention.

Andhra Pradesh is an important state for production and contribution to food reserves in the country. Rice–rice rotation is predominant in the coastal area. A recent report[10] of the Andhra Pradesh Agricultural University on 'Stagnating Rice Productivity in Andhra Pradesh' brings out many factors including irrigation, diseases and pests, and soil problems as the causes of declining or stagnating yield.

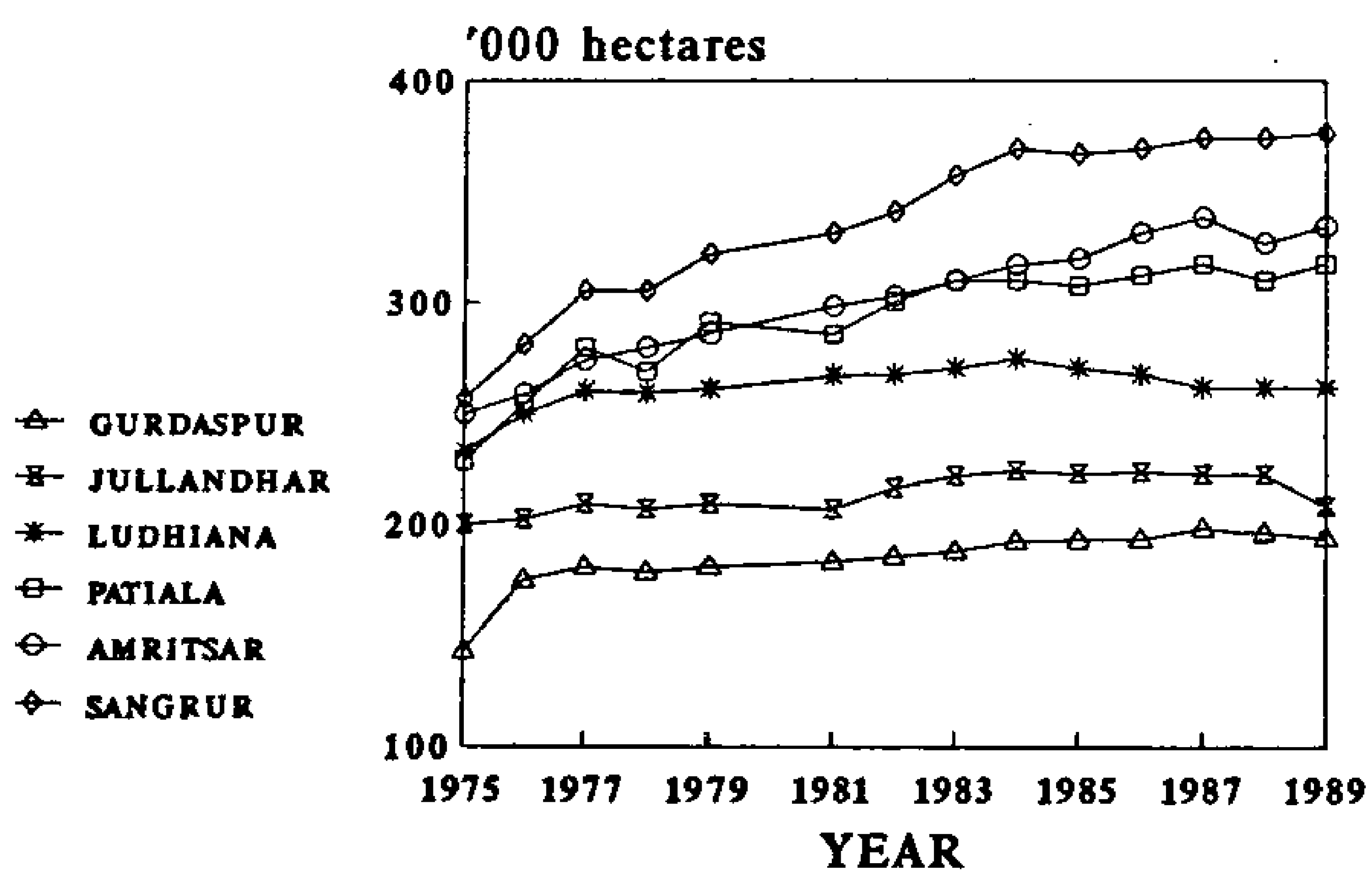

Figure 5. Expansion of wheat area in Punjab.

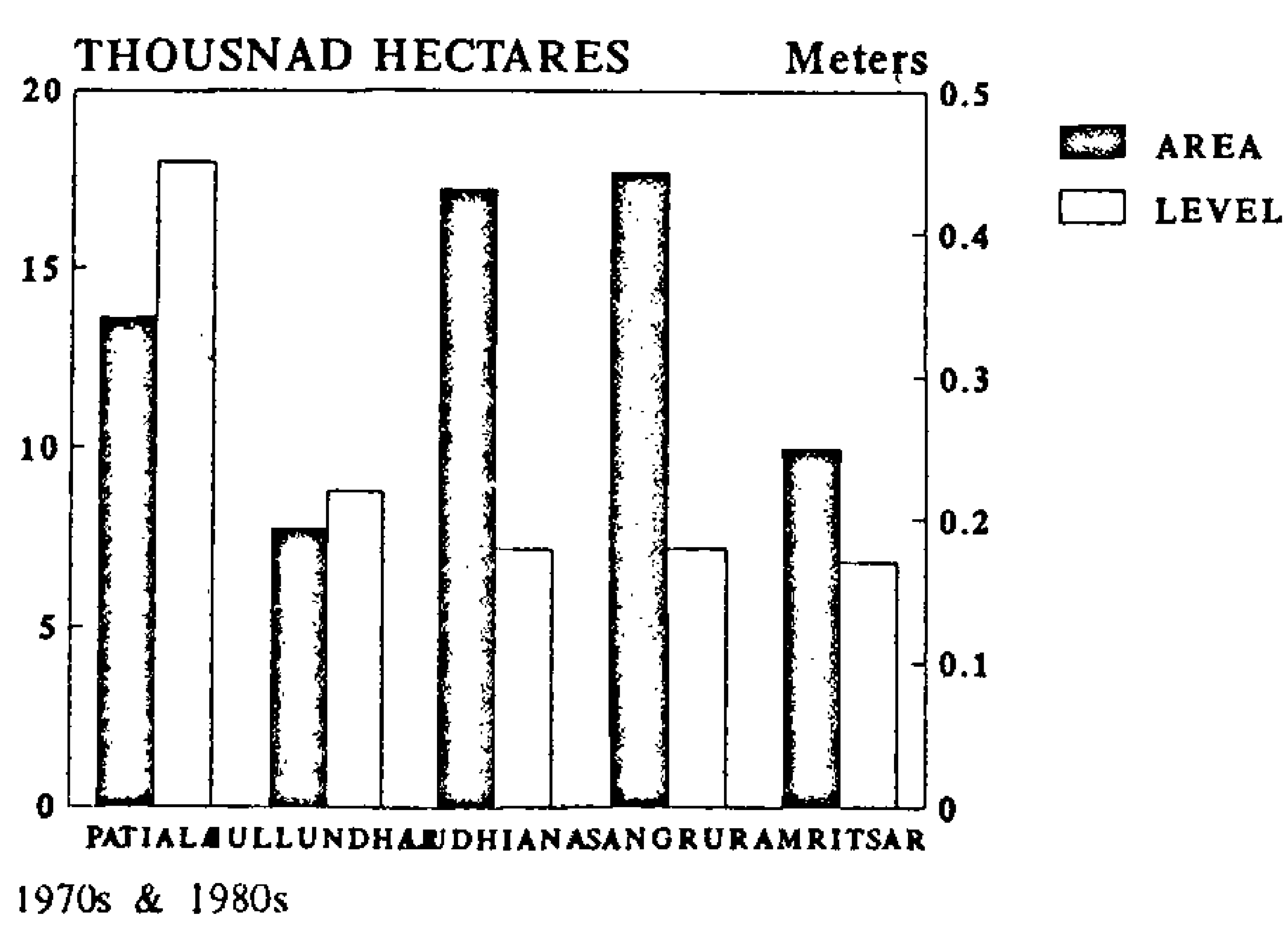

Figure 6. Groundwater fluctuations in October due to rice area expansion.

Groundwater pollution

Bajwa *et al.*[11] have investigated the problem of nitrate–nitrogen (NO_3–N) pollution of groundwater in Punjab where fertilizer use has been increasing. The samples were drawn from 236 tube-wells and more than 200 wells in cultivated area of several blocks. The NO_3–N content varied from 2.73 ± 1.22 to more than 10.0 mg NO_3–N per liter of water. The data on land use (Table 9) shows that the least amount of nitrate nitrogen occurred in rice–wheat system and the maximum was in vegetable crops. It was shown that the wheat crop which has a deeper root system is able to utilize nitrate from the lower levels. The vegetable crops received 15–20 t/ha of farm yard manure (FYM) in addition to 75 to 100 kg nitrogen per hectare. Therefore, the groundwater pollution with NO_3–N depends on the land use system and it is difficult to generalize the observation from any one cropping system.

Research for crop improvement

Crop improvement, particularly varietal improvement, has been a major objective of research in agriculture in South and South-East Asia. The collaboration between these countries and International Rice Research Institute, and CIMMYT from early 60s resulted in release of many high-yielding varieties. The IR8 in rice was the first to make impact on rice-paddy production. In India it gave rise to a variety, Jaya. However, there have been efforts to incorporate disease and pest resistance in new varieties, or to change their duration to fix them in a particular cropping pattern. In addition, there is a continuing effort to increase productivity, but on a large area basis or in experiments the yields of IR8 and Jaya have not been surpassed[12,13]. Data from IRRI is shown in Figure 7. Khush and his colleagues at IRRI are engaged in improving yield to 13.0 or 14.0 tons ha^{-1} of rice-paddy. There are indeed hybrids of rice which usually yield 0.5 to 1.0 tons ha^{-1} more than the existing varieties, but there is not much data to show if their sustainability has been evaluated. In the last five years the productivity of rice-paddy in China seems to be stagnating despite a larger area being planted with hybrid

Table 9. Nitrate concentration in groundwater samples under different land use systems

Land use systems	No. of tube-wells	% of wells containing 0–5 mg	5–10 mg
Rice–wheat	68	97	3
Potato–wheat	34	94	6
Vegetables	42	83	17

Location of the remaining tube-wells could be classified under a well-defined land use system.

rice. Therefore, it is important that research in this region should pay more attention to causes of stagnation or decline in yield, and attempt to develop indices for deterioration of methods of cultivation, soil and environment. Have we to think of fixing an upper limit of production in a given region or soil to ensure sustainability?

The improvement of wheat at CIMMYT as well as in India also shows a slowing down as expected. But what is worrying is that the productivity in some districts is quite close to the best culture in coordinated trials. Again a greater emphasis on basic mechanisms related to environmental degradation including soils is required to ensure continued growth in production of rice and wheat which are the major cereals produced and consumed in South and South-East Asia.

Environment aspects of land cover change

There is a global concern for the global climate which according to IPCC[14] is already showing the signs of change because of increasing concentration of greenhouse gases due to human activity. Among the various greenhouse gases, carbon dioxide, methane and nitrous oxide have been associated with land cover change and agriculture. Deforestation, according to some, has contributed to increased CO_2 in the atmosphere. There are some models through which biomass of a forest cover could be estimated. These models need validation at the sites because it is not only rainfall but soil, composition of species in a forest, climate, etc. which determine the biomass of a forest. Similarly the estimates of contribution by soil organic carbon to atmospheric carbon dioxide need to be validated. As stated earlier, there is now evidence to suggest that forests are accumulating carbon in India rather than contributing it to the atmosphere.

The IPCC[15] report attributed 110 Tg methane production from rice-paddy, largely based on experiments in Europe and California, USA. These experiments did not represent the conditions in which rice-paddies grow in a large part of Asia[16]. Measurements in India, China, Australia and other countries have clearly shown far lower values than given by IPCC. However, the 1995 IPCC Report does not state methane emission from rice-paddies but includes it in anthropogenic emission without attributing a value for rice-paddies. It states that stabilization of CH_4 and N_2O concentrations at today's levels would involve reductions in anthropogenic emissions of 8% and more than 50% respectively.

Estimate of nitrous oxide shows its increasing concentration in the range of 3.0 to 4.5 Tg annually. Several sources have been identified, including the cultivated soils. How does agriculture influence production of nitrous oxide? If poor efficiency of nitrogenous fertilizers in tropical countries is one of the possibilities, then we have to obtain data. There are now techniques, such as the use of encapsulated urea with calcium carbide which reduces emissions of both methane and nitrous oxide (Figure 8).

Conclusions

1. Land cover and land use changes have occurred in South and South-East Asia as happened anywhere else in the last century and early part of this century. However, the present data indicates very little change in forest cover in the last two decades.
2. During the past three decades, food production, largely of rice and wheat increased at a rate higher than population growth rate. The region has become dependent on rice and wheat which have shown signs of stagnation in productivity.
3. In some high-productivity areas, there is evidence of changes in groundwater level, and also of groundwater pollution.
4. There has been very little progress, if any, in the productivity of rice as well as wheat since the

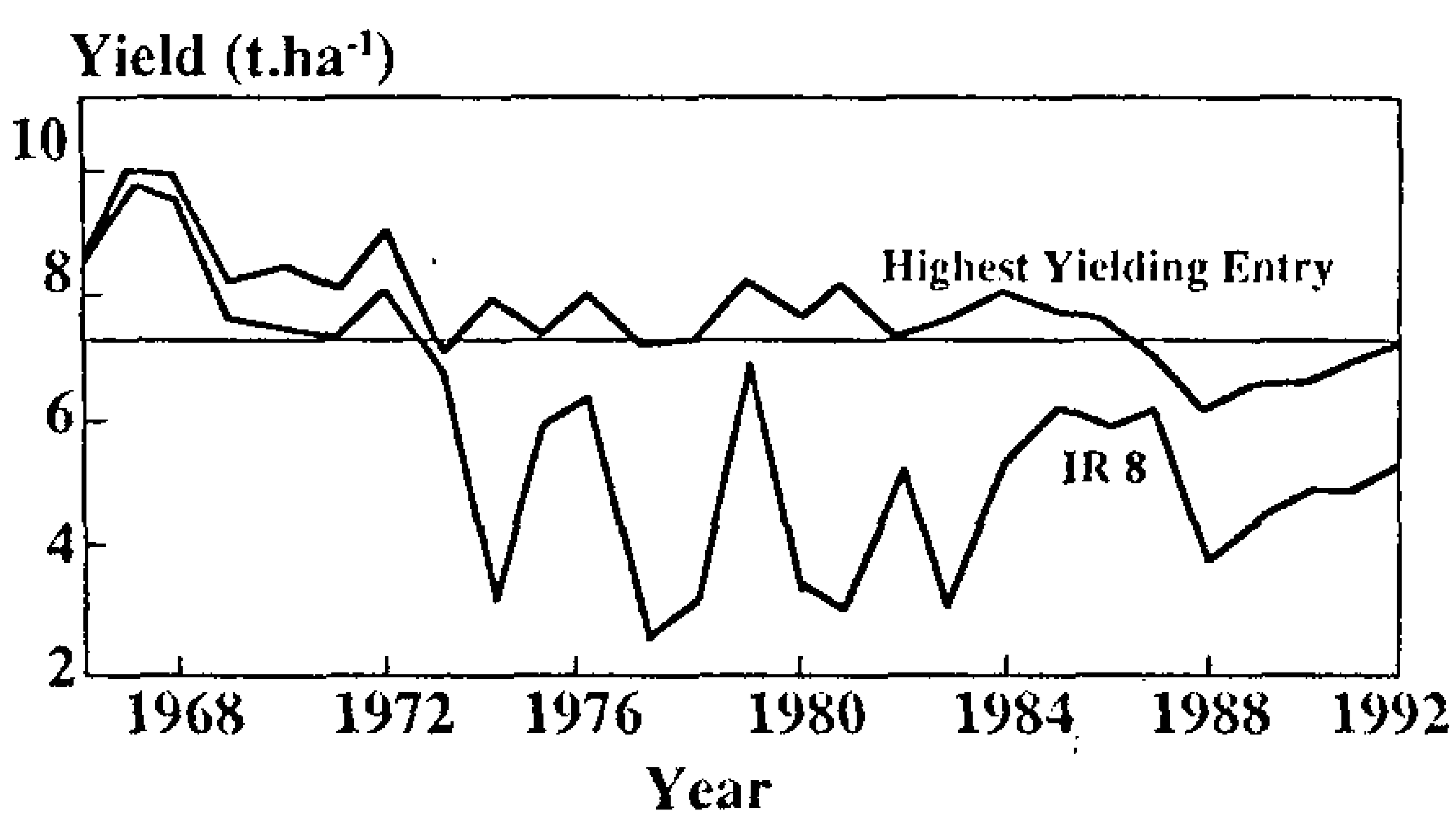

Figure 7. Grain yield of IR8 and the highest yielding single entry in dry seasons, 1966–90, at IRRI (G. S. Khush).

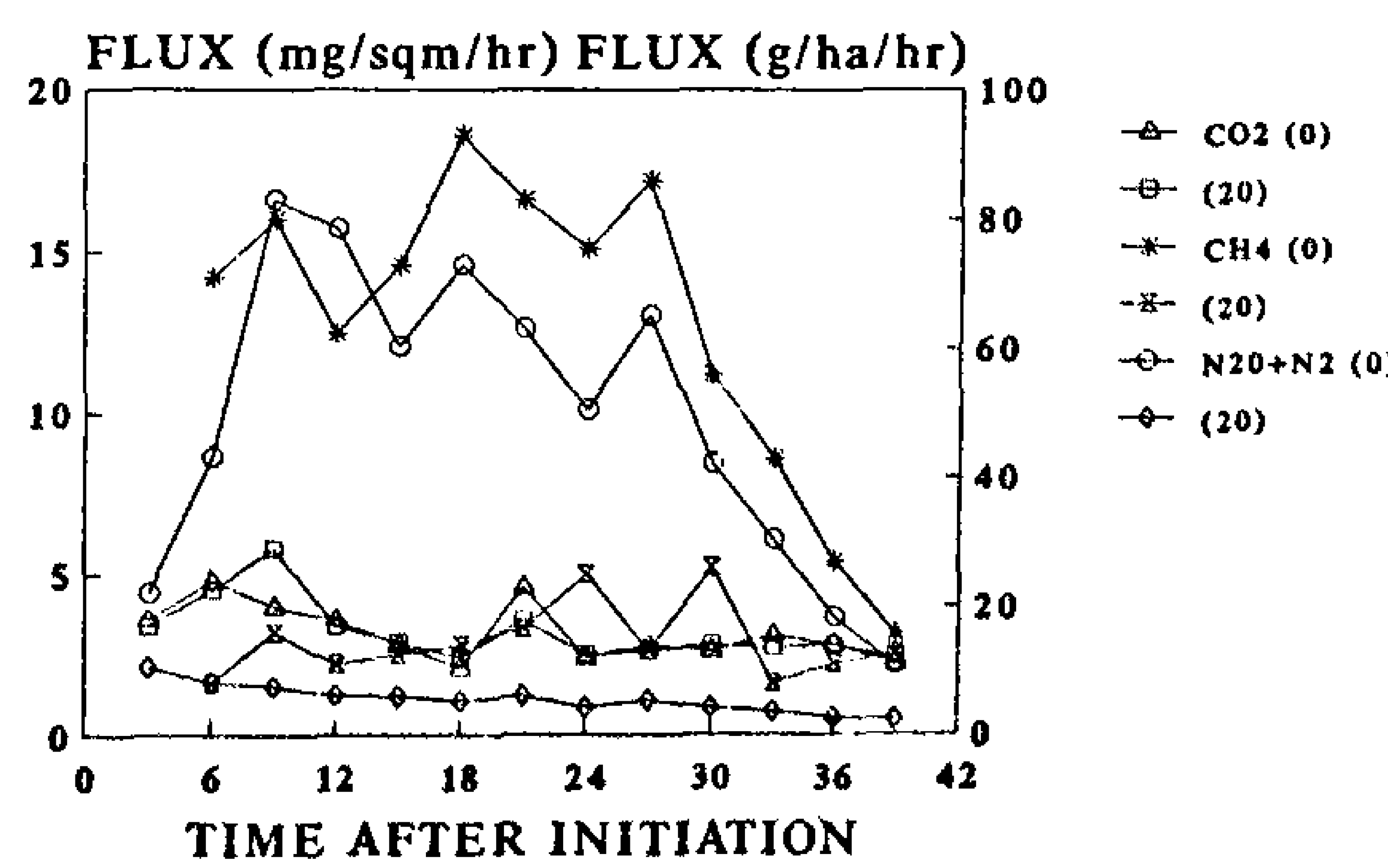

Figure 8. Effect of encapsulated calcium carbide on CO_2, CH_4 and N_2 flux in rice.

high-yielding varieties such as IR8, Jaya and kalyansona were released.

5. A decrease in production of coarse grain is a matter of concern. It is these crops in combination with tuber crops such as cassava and sweet potato which could have a profound effect on food security in combination with soybean and groundnut. Food technology should play an important role in future in making more effective use of these crops.
6. In India a greater emphasis on rainfed areas is essential to ensure sustainability of the present day high-productivity regions.

Action points

1. The problem of land use changes occur at microlevel that is the village level. Therefore, action should also start from there.
2. There is an urgent need to develop indices for unsustainability which could be used for monitoring different components of environment.
3. There is very little understanding of environmental economics in this region with an intensive involvement of various disciplines of science. Often arbitrary economic values are used which can lead to either complacency or alarm. Therefore, a new approach of working has to be developed.
4. A better database is needed to make use of models for aspects related to global change.
5. Regional programmes should be developed on land cover changes and agriculture sustainability which should include site visits, discussion with participants.

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ACKNOWLEDGEMENT. I thank Dr R. Khanna-Chopra, Mr C. Vishwanathan and Mr Rajesh Patel for the help in preparation of this paper.