Agriculture in India: Land use and sustainability

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Reviewing land use pattern it is observed that large forest areas have been converted to cropland creating unprecedented ecological imbalance with no scope of expansion of agricultural land without further damage to natural environment. In face of increasing demand for food grains intensive agriculture based on irrigation-fertilizer-high-yielding seed technology is the common practice. However, the intensive agriculture gives rise to serious environmental problems like pollution of water bodies with fertilizer and pesticides, contamination of ground water and land degradation apart from the loss of indigenous crop species and genetic diversity. Sustainable agriculture with its emphasis on preservation of ecology, optimization of economic and social benefits and conservation of energy is seen to provide stable and lasting solution. Ways and means have been discussed to operationalise the sustainable agriculture. Some of the aspects of sustainable agriculture have been illustrated through an example comparing farming practices of two farmers in two different regions of Bareilly district of the state of Uttar Pradesh in Northern India.

Introduction

India can safely be characterized as an agricultural country despite the recent spurt in manufacturing and services and the declining share of agriculture in the national income, since majority of its workforce (~ 65%) are still engaged in agriculture and allied activities. It has been the noblest profession in India since the time immemorial and has been carried out on sustainable basis. It is only relatively recent phenomenon that large-scale forest areas, grazing lands and waste lands have been converted into croplands to support the rising population, which has caused ecological imbalance and atmospheric pollution. With no further scope for expansion of agricultural land efforts have been made to enhance the production of food grains using high-yielding variety of seeds, fertilizers and irrigation alongwith advanced farm equipments. However, so-called green revolution is cofined to a few crops, viz, wheat, rice and maize and has been possible only in restricted areas, i.e., Punjab, Hariyana and Western Uttar Pradesh and certain selected districts of Andhra Pradesh, Maharashtra and Tamilnadu. Naturally much work is needed to lift the agriculture to a level where it is least affected by vagaries of monsoon and needs little from outside the farm, i.e., lesser dependence on chemical fertilizers and water.

The limited success of green revolution has been a mixed bag in that it has given rise to new set of problems: overuse of water and fertilizers. Excessive use of water results in water logging and salinization whereas excess of fertilizers and pesticide cause pollution of waterbodies contamination of ground water. India has the largest area of irrigated land (55 million hectares) of which about one-third land is already degraded and 7 million hactare have been abandoned[1] . In such a situation a renewable and lasting alternative, sustainable agriculture, has to emerge for successful agricultural revolution. In the present paper after a review of land use pattern the ills of intensive agriculture is delineated and need for sustainable agriculture has been emphasized. Possible methods for operationalizing the sustainable agriculture are discussed. An example illustrating sustainable farming is presented.

Land Use Pattern

Of different uses of land---forests, pastures, human habitations, and various economic activities agriculture is the prime one and most important for the survival of the mankind.

At present India has 23% forest cover, 3% pastures and grazing land, 46% area is under agricultural use, 14% land is barren, 6% land is cultivable waste land and remaining 8% is fallow land[2]. Compared to India situation, forests cover 30% of total land area of the world, 26% are pastures and grazing lands and only about 11% of land is used for agriculture. The remaining land about 33% are marshy land, desert, scrub forests, bare rocks, ice and urban areas. About one-third of this land, i.e., 11% is devoid of any plant cover and is completely barren[3]. Though the deserts and other unproductive lands are generally unsuitable for intensive human use, they are important in biogeochemical cycles and act as a refuse for biological diversity.

The proportion of land area under agricultural use in India (46%) is much large compared to world (11%). According to some agricultural experts about half of the forests in Africa and grazing lands in South America could be converted to croplands if proper inputs of water, fertilizer, erosion control and farm equipments are there. This could feed much larger population but then a sustained intensive agriculture could give rise to serious environmental and social problems[3]. The area under agriculture has increased from 118.7 million hectares (39%) in 1950-51 to 142 million hectares in 1995-96. This increase in agricultural land is largely as a result of clearance of forests under population pressure. According to a conservative estimate deforestation has been going on at an alarming rate of 1.3 to 1.5 million hectares every year through the nexus between forest officials and timber contractors. Himalayan forests are likely to disappear completely in next 30 to 35 years if the continuing deforestation is not checked immediately. Similarly forests are being cleared in Western Ghats and Eastern Ghats.

Large-scale destruction of forests in India has to be seen in historical perspective. During the British rule large forest areas were cleared for agricultural use, since the Government preferred extensive cultivation to ensure food production for rising population. The policy was convenient for Government revenues from timber, which was also needed for railways in India and U.K. According to a 1894 circular "wherever an effective demand for cultivable land exists and can only be supplied by forest area, the land should ordinarily be relinquished without hesitation"[4]. After independence the old policy was discontinued but by then large forest areas had been utilized for permanent cultivation creating a situation that threatened the physical and climatic balance of the country. This was the reason the new forest policy of 1952 laid guidelines that one-third of the geographical area of the country should be covered by forests and trees, in which mountainous and hilly regions should have 60 percent coverage while plains should have 20 percent coverage. However the said guidelines have been followed only in its breach and pace of deforestation has intensified after independence. Thus between 1854 and 1952, i.e., roughly a span of a century before independence the forest cover came down from an estimated 40 percent to 22 percent of the land area, an annual decline of about 0.2 percent. But after independence between 1952 and 1988, i.e., in a short period of 36 years the forest cover had come down from 22 percent to 12 percent of the land area, an annual decline of 0.4 percent.

Massive deforestation has resulted into serious problems of environmental instability and ecological imbalance including atmospheric pollution. Moreover, rapid increase in modern transport systems, mining and quarrying operations as well as industrial production have been creating atmospheric pollution. The greenhouse gases-carbon dioxide, nitrous oxide, methane and chlorofluorocarbons contribute significantly to the atmospheric pollution. Large-scale deforestation has exposed sensitive catchment areas in Himalayas and other hilly areas to soil erosion. The run-off rain water from denuded areas have disastrous effects on the cultivated lands of the plains, cause floods with massive siltation of rivers. Ganga is only second to Huang (yellow) river in China in silt carrying; it carries 1455 million metric tons of mud to the Bay of Bengal every year[5]. Much of this sediment comes from the Himalayas. In the context of widespread soil erosion and atmospheric pollution the forest policy of 1988[6] has set a goal of one-third forest cover with priority to the objective of ensuring environmental stability and maintenance of ecological balance including atmospheric equilibrium. In hills the tree cover should be two-third of the area in order to prevent erosion, land degradation and to ensure stability of fragile ecosystem. By increasing the area of protective forests, denudation in the catchment areas of rivers and streams can be controlled. Forests check the extension of sand dunes in deserts and coastal tracts.

Unlike forests grazing lands are open spaces and are more attractive for human occupation. Often they are converted to croplands, urban areas and other human-dominated structures. Area under grazing lands has gradually declined and has been converted to cropland. Though grazing lands are 3% of total land area, other lands that are used for grazing (forest 23%, fallow land 8%, barren 14%, and wasteland 6%) even if used seasonally and/ or occasionally, together constitute more than half of the geographical area of the country. This land is used for raising animals who provide us milk, meat and other valuables like wool etc. Some nomadic tribes who adjust to varied land and climate conditions live by livestock only and produce handsome yields from harsh and inhospitable regions: Gujjars in Garhwal Himalayas and Kashmir and Bakerwals in Kashmir come in this category. While Gujjars tend buffalo and produce milk Bakerwals herd sheep and goats providing valuable wool, milk and meat. Camels in desert area feed on thorny bushes and provide useful service. Although grazing lands appear to be uniform and monotonous they are quite rich in species helping in maintaining ecological balance and diversity.

Intensive Agriculture

As for agricultural land, there is hardly scope for further expansion; on the contrary there has been marginal decline in the crop area due to construction activities on prime agricultural land on account of urban expansion and industrialization etc. As mentioned earlier, only 11 percent of the total land area of the world is under cultivation, which is 1441 million hectare whereas in India cropland area is 141 million hectare, which is 46 percent of the land area of the country. At the world level another 40 percent land can be converted to cropland but much of this land serves as a refuse for cultural or biological diversity or being marginal lands suffering from constraints such as steep slopes, shallow soils, poor drainage, tillage problems, low nutrient levels, excess soluble salts, or acidity only limited number of crops can be grown. Such lands are already under cultivation in our country and with growing population the per capita availability of cropland is bound to fall. In order to meet the food requirement of growing population the yield of the cropland must be increased with the use of irrigation, fertilizer, pesticide and high- yielding variety of seeds. Most of the developing countries have used intensive agriculture on existing lands to meet their needs and India is no exception. However, the intensive agriculture based on irrigation, fertilizer, pesticides, high-yielding varieties of seeds and advanced farm equipments has its own limitations and problems:

- New high-yielding varieties of seeds are really "high responders" rather than high yielder, i.e., with increasing amount of fertilizer and water they respond more efficiently and yield is higher than other varieties. Under poor conditions, i.e., in absence of sufficient water and fertilizer these seeds do not give higher yield compared to traditional crops[7]. It is presumed that high dose of fertilizers cause faster depletion of soil nutrients and in a way we are mining soil, since nutrients are being used much faster than they are being replaced. On the other hand, with the use of organic manures the soil nutrients are maintained for longer periods.
- In the context of crop breeding the question has been raised whether new varieties will continue to be produced that will maintain these high-yields. Throughout the world native crop varieties are being replaced by these new crops and genetic resource available to breeders is being seriously diminished. Many indigenous crop species have been lost.
- With only new hybrid varieties of seeds being sown we are fast losing genetic diversity, which was source of major crops.
- With a single crop variety all over the fields there is real risk, since some disease might damage the entire crop resulting in complete dislocation of production.
- Poor farmers cannot afford high value farm equipments, fertilizer, pesticides and high- yielding seeds and thus only rich farmers are able to participate in the green revolution. Further, with surplus production the prices come down making poor farmers worse off than before.
- Most farmers over water the fields often resulting in water logging. Irrigation with saline water results in salinization that kill plants. Irrigation problems are major source of land degradation and crop losses.
- Often farmers are unaware of nutrient content of the soil in their field or the need of the crops and use excess amount of fertilizers. This is not only wastage of the money but is major cause of the environmental degradation. Fertilizer from fields join the run-off and pollute the aquatic ecosystem. Nitrate levels in groundwater have been found to be too high to be safe in many places where intensive agriculture is practiced.

In view of the above points it is evident that the intensive agriculture cannot be sustained without creating serious environmental and social problems. It is true that in many developing countries and in many regions of our own country intensive agriculture can be used to increase the farm production. But then it is clear that the intensive agriculture does not provide the lasting solution and we should think of the ways to make agriculture more stable and renewable. Thus the real answer is sustainable agriculture[8,9].

Sustainable Agriculture

The sustainable agriculture may be defined as any set of agronomic practices that are economically viable, environmentally safe, and socially acceptable.

If a cropping system requires large inputs of fertilizer that leak from the system to pollute ground water, drinking supplies and distant coastal fisheries, the system may be sustainable economically as the long-term supply of fertilizer is stable and the economic cost of fertilizer is easily borne by larger grain production but it is not sustainable environmentally or socially, since it does not cover the cost of environmental damage or social costs. The organic agriculture focuses on "living soil", on optimizing the use of biological processes and on avoiding the use of synthetic chemicals and fertilizers.

Advocates of sustainable agriculture agree with biological focus and hope to reduce but not necessarily eliminate chemical use. In the context of sustainable agriculture another term "alternative agriculture" has been prominently used. Definition of alternative agriculture sheds much light on operational aspects of sustainable agriculture. Any food or fiber production that has

- a more thorough incorporation of natural processes,
- reduced use of off-farm inputs with less harm to environment and consumers,
- a more productive use of biological and genetic potential of plants and animals,
- a better match between cropping patterns and the physical capacity of lands and,
- an improved emphasis on conservation of soil, water, energy and biological resources, is defined as alternative agriculture.

The normal agricultural practices using irrigation, chemical fertilizer, pesticides and high-yielding variety of seeds is called conventional agriculture. With increasing use of chemical fertilizers and pesticides the conventional agriculture is major source of pollution of inland water bodies and coastal seas. There has been growing criticism of conventional agriculture for its side effects, the "external costs" which impact communities, the environment, and human health.

As for indicators of sustainability there is no single prescription. Sustainable practices will vary by cropping system, local environment and socio-economic system. Still, experience tells us that locally sustainable systems tend to be more resource conservative than less sustainable system and tend to rely less on external inputs and more on internal ecosystem services.

Resource Conservation:

One very important ecosystem resources, soil organic matter, declines rapidly in almost all cropping systems following initial cultivation- typically 40-60 percent of original values within a few decades. Soil organic matter is valuable resource, providing habitat and energy for soil organism, a soil structure favorable for plant growth and water retention and a chemical structure favorable for nutrient retention.

Cropping practices that conserve or enhance soil organic matter buildup will invariably enhance environmental and often the economic sustainability of cropping systems. Crops grown in high organic matter soils have a better water and nutrient environment and require less and fewer external inputs for the same productivity. High-organic matter soils help to check soil erosion and run-off and thus better protects downstream environments from organic impact. Therefore, cropping practices that conserve soil organic matter can be considered more sustainable than those that do not. Often, however, there are trade-offs that require conservation efforts to be evaluated in the overall context of sustainability. For example, conservation tillage typically slows or stops soil organic matter loss and thus can be considered a resource-conserving, sustainable cropping practice. However, in absence of tillage we need herbicides to control weeds that have environmental and economic cost different from those from tillage. Ideally, such trade-offs can be minimized. Each cropping practice must be evaluated in the light of overall sustainability of a system.

Ecosystem Services:

Farms provide ecosystem services to organisms within the farming system as well as to organisms in the surrounding landscape and to local communities. Services such as pollination, water retention and ground water recharge, a particular light environment, or food sources are integral to the functioning of healthy ecosystems. In modern cropping systems many services provided by original ecosystems prior to its conversion to agriculture have been suppressed or ignored in favour of services provided by external inputs. In a nitrogen-poor native ecosystem, biological nitrogen fixation by native legumes such as “arhar” (yellow pulse) might be a principal source of fixed nitrogen; modern cropping systems rely almost exclusively on industrially fixed nitrogen provided as inorganic fertilizer. In a native or unmanaged system, insect herbivore is suppressed largely by plant diversity and structural complexity that enable insect and vertebrate predators to keep the plant pests at bay. In modern practices insect pests are controlled with insecticides that also kill insect predators. Managing a cropping system with legumes or greater plant diversity would allow the ecosystem to provide more of the services that are provided by external inputs. Similarly animal manure produced on farm and recycled to the field can replace fertilizer use. Agricultural research is helping to identify the ways in which management can add ecosystem services that both enhance resource availability and reduce environmental costs of agriculture. At societal scale the farms provide valuable services to neighboring communities.

Examples of sustainable cropping systems are provided by bush-fallow rotation systems and mixed farming systems. Before the advent of continuous cropping systems bush-fallow rotation system was indigenous to many cultures and “Jhum cultivation” in North-East is still used today in certain pockets. In these systems a plot is cleared of native vegetation and is cropped. When nutrients are depleted after few crops the plot is abandoned to “bush-fallow” and another plot is cleared and cropped. With rising population this type of sustainable cropping has limited utility today.

The mixed farming system has several production lines with crops, trees, animals or combinations of crops and animals. Even now small land owners requiring a farm family self-reliance produce wide array of goods that is primarily to meet family and local market needs for an ensured, year round supply of food, fuel and building materials. The diversity of land use provides a range of ecosystem services, including precipitation management, ground water recharge, wildlife habitat, an environment usually conducive to adequate pest-predator balance, and some mitigation of harsh climate conditions. The mixed plant community provides shade, wind protection, privacy, and many other, often seasonal, assorted products and services. The range of outputs has recently been called the multifunctional character of agricultural land (FAO, 1999)[10]. In areas with high density of population, small farms and the need for producing a wide range of products in often marginal production environments, a very diverse type of farm enterprise mix is common. In areas with heavy rainfall trees are part of native vegetation and may be a very important part of farm productivity. Usually animals are the part of the enterprise because they consume farm residues and add significantly to farm productivity.

In most of the country there is little area of undisturbed forest, and only a few exclusive animal farms are there. In many parts where modest levels of rainfall are there and/ or in winter months fuel for cooking and heating becomes a problem especially for poor households. Often trees are cut for firewood, farm residues and animal residues are burned. This leads to resource degradation and loss of production potential. The system rapidly loses crop nutrient holding and recycling capacity and its ability to intercept and retain rainfall decreases.

We conclude that sustainable agriculture is far more preferable if we take into account the resource conserving potential and ecosystem services provided by it and the grave environmental cost paid by society in conventional farming system based on water-fertilizer- high -yielding seed technology.

Sustainable farm practices: An Example: In order to illustrate some aspects of sustainable agriculture we compare the farming practices of two farmers engaged in production of rice in two different regions of Bareilly district of the state Utter Pradesh in northern India: Faridpur Tehsil and Baheri Tehsil. While Faridpur is situated in southern part of the district where soil is loamy and irrigation is largely dependent on ground water extracted by tube wells and pump sets Baheri is situated in the northern part, the Tarai belt bordering Uttranchal, the hill state newly carved from Utter Pradesh. Soil in Baheri region is largely black and much more fertile compared to Faridpur and irrigation is mainly based on canal water obtained from river Bagul coming from Uttranchal. In Table I we present the cost-benefit analysis of rice production based on data obtained through private conversation with the concerned farmers. Apart from the explicit information presented in the table what is not obvious but revealed during private conversation is the fact that farmer in Faridpur (A) with land holding of 1.33 acre is essentially a marginal farmer dependent on hired farm equipments, irrigation water and carries out most of farm operations himself and through farm labourers the one in Baheri (B) with a land holding of 7.5 acre is a medium farmer, who owns a tractor but depends on hired combine harvesting machine plus hired labourers for different farm operations and clears his field of herbicide solution after two days of its application before planting of seedlings otherwise it would kill the main crop also. The cost of different farming operations are as per prevailing market rates in the regions though some of the operations might have been performed by the farmers themselves and not hired from the specialized service providers; thus, for instance, farmer A hires tractor for ploughing the field but does most of other operations himself and through his family members whereas farmer B uses his own tractor for ploughing but hires farm labourers for other operations. The presentation of cost based on market rates facilitates a direct comparison between the two.

A perusal of the table I reveals that both the farmers use essentially intensive agriculture using irrigation-fertilizer-high-yielding seed technology. Apart from minor differences in different farming operations and costs incurred three basic differences between the two are:

(i) Irrigation: Farmer A uses underground water extracted by tubewell on hourly rental basis and has to irrigate the field 5-6 times, after initial heavy irrigation at the time of sowing when there are no rains at all; however the actual irrigation used depends on the amount and timing of rainfall in the area. On the other hand farmer B uses canal water for irrigation throughout the duration of the crop on the basis of nominal charge of Rs. 60 per acre. There is possibility of over use of water by farmer B resulting in waterlogging, since water is available almost free.

(ii) Use of pesticides and herbicides: While farmer B uses pesticides to control pests and herbicides to get rid of unwanted weeds from the field the farmer A does not use these harmful chemicals. As a consequence farmer A has to incur an expense of Rs 1020 = per acre on hoeing to extract weeds manually and suffers the risk of damages to the crop due to possible attack of pests. With the use of pesticides and herbicides at much lower cost (Rs 600=) farmer B gets rid of weeds and pests but in the process he causes serious damage to environment by releasing these chemicals in the open to be carried off to waterbodies.

(iii) Harvesting: while A uses manual harvesting B uses rented combine machine for this purpose and is somewhat economical saving Rs 420 = per acre compared to A. But due to manual harvesting A gets hay which over compensates the costly manual harvesting and at the time gets gainful employment for himself and his family members and for some other farm labourers too.

We observe that farmer B gets better return compared to farmer A but B's agricultural practice is not safe environmentally and socially less acceptable. Thus the farm practices followed by A are much better on sustainablility than that of B.

As stated earlier, for sustainability the use of animal manure is preferable to that of chemical fertilizers. Since manure is not available in sufficient amount and therefore any definite figure could not be made available but the experience of both the farmers tells us that the use of animal manure alongwith much reduced amount of fertilizers fetches much better yield and at the same time ensures maintenance of higher level of fertility for longer period. With almost universal acceptance and practice of conventional agriculture based on irrigation-fertilizer-high-yielding seed technology the local wisdom and experience calls for periodic use of animal manure and crop rotation for sustainability of yield as well as fertility of soil.

We see that farmer A relies more on manual labour and causes lesser damage to environment by not using pesticides and herbicides and thus captures the essence of sustainable agriculture. The practice of relying on manual labour not only creates additional jobs in rural areas it adds to energy conservation saving on crucial fossil fuels used in farm equipments such as harvesting machines. Not using pesticides A suffers possible damage to crops on account of pests attack while non use of herbicide forces him to incur additional cost on hoeing but then it ensures the preservation of ecology and social benefits in terms of public health. Thus sustainable farm practice should attempt preservation of ecology, optimization of economic and social benefits, creation of additional jobs and conservation of energy.

The mainstay of staple food in our country are wheat and rice and much of agricultural research and extension services have concentrated on these crops. The high-yielding improved varieties of seed require high doses of water and fertilizers, archetypical vehicle of green revolution. Concomitants of high doses of water and fertilizers are environmental problems: waterlogging, salinization of soil, shortage of water, falling water table, contamination of underground water, and pollution of waterbodies with chemical fertilizers and pesticides posing serious threat to aquatic life and public heath. Obviously agricultural research should focus on development of high-yielding variety of seeds that need lesser amount of water and fertilizers, diversification in terms of development of improved variety of seeds of other cereals like millet, jowar, gram, barley etc. so as to get good yield even from rain fed areas and popularizing farm practices focusing preservation of ecology, optimization on of economic and social benefits, optimization in use of labour and machines and conservation of energy. In more practical terms.

(i) Field should be protected with bunds to avoid the loss of nutrients and fertilizers with the run-off rain water.
(ii) As for as possible animal and green manures should be used, which is possible with mixed farming involving crops, trees and animals.
(iii) Diversification and rotation of crops.
(iv) Harvesting of rain water to improve the availability of water.

In short, a small farm management to improve productivity, profitability and sustainability of the farming system will go a long way to ensure the all round sustainability.

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Table I: Various expenses and yield in respect of rice production per acre. A comparison between farm practices of two farmers A (Mr. Naresh Village: Razau, Faridpur, Bareilly; land holding 1.33 acre) and B (Mr. Ramesh Kumar Village: Gowari, Baheri, Bareilly; land holding 7.3 acre)

	A Mode	Expenses Rs	B Mode	Expenses Rs
Plough	Rented tractor	1200	Own tractor	1200
Irrigation	Rented tubewell	3600	State canal	60
Fertilizers	Urea & zinc	960	Urea & zinc	960
Seed/Seedling	Own nursery Sarbati	380	Own nursery Narendra Pant4	150
Pesticides/Herbicides	Not used	-	Solution	600
Sowing	Manual	840	Manual	720
Hoeing	Manual	1020	Not needed	-
Harvesting	Manual	1200	Combine	780
Land Rental	Rented land	2400	Landowner Himself	4500
Subsidy		-	Subsidized Canal irrigation*	3540
Total Expenditure		11,600		12,510

Yield	Paddy 18 Quintal 1404 15,840 @ Rs780 per quintal Hay 1800	Paddy 30 quintal @ Rs630 per quintal** 18,900
Profit	4240	6390

* Canal irrigation is almost free: Rs 10 per bigha (local unit of land ≈ one sixth of an acre) for any amount of water used for the crop and such differential from the market rate is considered to be subsidy from the state

** In harvesting with combine harvesting machine, hay is not available.