UNIT 5 SUSTAINABILITY: THE NEW PARADIGM

Structure

5.1 INTRODUCTION

The introduction of high yielding varieties in the developing countries required intensive use of fertilizers and the past few decades witnessed remarkable increase in agricultural productivity. The agro-technological innovations also brought about an element of resilience in agriculture to ward off the threats of famines. The impact of Green Revolution in India on mitigating hunger and on bringing an overall rural prosperity was so dramatic that India emerged as a role model for many developing countries.

But success always has its costs, and Green Revolution has been no exception. Recent evidences, though not always verifiable, support the adverse impact of excessive use of agro-chemicals including fertilizers and water on the crop productivity, environment and health of living beings. The productivity growth rates of major food crops like rice and wheat have started stagnating, or even declining, in some intensively cultivated areas, thus posing a threat to national food security.

Today agriculture in developing countries faces major problems such as depletion of soil nutrients and water reserves, increased incidences of soil salinity and water-logging, decline in factor productivity, resurgence of pests and diseases and increased environmental pollution. Continuous diversion of prime agricultural lands to non-agricultural purposes and fragmentation of farm holdings have further aggravated the problems. It is in fact due to these pressing problems that sustainability of agricultural production systems and environment has emerged as a serious concern.

The amount of food needed would keep increasing as we progress in time. Multiple crops would need to be grown from the same land which implies increased mining of soil for plant nutrients. We know that large amounts of plant nutrients are lost due to soil erosion. The question is: Will the soils in South Asian Countries be able to sustain such heavy nutrient mining? Deficiencies of several micronutrients are already showing up in large areas in these countries. This is just one indicator of decreasing sustainability of our agricultural production system. The sustainability of environment and other natural resources like water is also being questioned by politicians, policy makers, researchers and the farmers themselves. Therefore, in this unit we sensitise you to the issue of sustainability in agriculture.

Objectives

After studying this unit, you should be able to:

- explain the concept of sustainable agriculture;
- describe the parameters of sustainable agriculture; and
- discuss various approaches for practicing sustainable agriculture.

5.2 CONCEPT OF SUSTAINABILITY

Sustainable agriculture is a loosely defined term that encompasses a range of strategies to address the **problems of agriculture**. These problems include

- loss of productivity from soil erosion,
- non-judicious use of agro-chemicals particularly pesticides and fertilizers,
- pollution of surface and ground water due to agricultural practices and inputs,
- diminishing supply of non-renewable energy sources, and
- decreased farm income owing to low commodity prices and high production costs.

Thus the **concept of sustainability** has several dimensions: **socio-economic**, **cultural** and **environmental**.

Depending upon the stage of development of scientific agriculture, extent and quality of natural resources, resource base of the farming community, intensity of biotic pressure etc., sustainability has different meanings for different socio-economic strata in the developed and developing countries. It is a complex concept which is generally seen as human-centred, long-term and involving interaction with natural systems.

Giampietro et al. (1992) noted that agricultural production systems optimized through economic indicators ignore the fact that human managed systems may be degrading human resources by consuming non-renewable sources and reducing the capacity of some parts of the natural systems to renew or recycle. Adams et al. (1992) also highlighted the need for linkages between economic and ecological indicators of changes in land use. In view of this, FAO, (1989) observed that

The goal of sustainable agriculture is to maintain production at levels necessary to meet the increasing aspirations of an expanding world population without degrading the environments.

Before **After**

Fig.5.1: Sustainable agriculture should help in meeting food needs without degrading the environment

Janvry and Garcia (1988) emphasized the need for gender equity in sustainable agricultural production systems. Thus from the viewpoint of developing countries, sustainable agricultural production must:

- meet the changing food, feed, fibre and fuel requirement of the nation,
- assure adequate profit to the farmers,
- conserve and, if possible, improve the natural resource base,
- prevent the degradation of the environment,
- discourage regional imbalances, and
- encourage gender equity.

All these measures of sustainability are subjective rather than quantifiable concepts. Two indices are commonly used to identify the practices which give maximum sustainable yield or maximum sustainable income. These are 'Sustainable Yield Index (SYI)' and 'Sustainable Value Index (SVI)'.

Sustainable Yield Index (SYI)

SYI is defined as

$$SYI = \frac{Y - \sigma}{Y_{max}}$$

where Y is the estimated average yield of a practice over years, σ is its estimated standard deviation and Y_{max} is the observed maximum yield in the experiment. In calculating SYI, the negative values of $(Y - \sigma)$ should be takes as zero since yield is always a positive quantity. With this premise, the index takes values between zero and unity. In this index, σ quantifies the risk associated with the average performance Y of a treatment. When $\sigma = 0$ and $Y = Y_{max}$, SYI = 1.

Sustainable Value Index (SVI)

In the case of cropping systems, since more than one crop is involved, the economic assessment of these systems becomes important. In these situations, obtaining maximum sustained level of income is more desirable. To asses these situations on the basis of sustainable income, the index called Sustainable Value Index (SVI) is used. For arriving at SVI, the monetary values of economic produce are used instead of yield values. On one end of the spectrum are the developed countries with almost a zero growth rate of agricultural production, and threatened with a problem of over-production of agriculture and environmental degradation through industrialization and excessive use of agro-chemicals. On the other end are developing countries like those of the South Asian Region with population growth outstripping agricultural productivity growth. They need to produce more and more food, fibre and fuel from less and less of land. At the same time they are facing the ill effects of modern agricultural practices on the environment.

In South Asian countries, it is envisaged that if the current practice of exploitative management of natural resources and low productivity of agriculture continues, a child born today has less chance of getting adequate food to eat, enough space to live, clean water to drink and pure air to breathe in the years to come. Hence, sustaining the past achievements without deterioration in environment, particularly soil and water resources will continue to be the greatest challenge before agriculture in developing countries like ours.

SAQ 1

Why has the issue of sustainability become so important? Explain in the specific context of your region/country.

5.3 PARAMETERS OF SUSTAINABLE AGRICULTURE

You have just studied that sustainable agriculture involves successful management of resources to satisfy changing human needs while maintaining or enhancing the quality of environment and conserving natural resources. In predominantly agriculture-driven economies, sustainable agriculture could more aptly be defined as the one that over the long-term:

- enhances environmental quality and the resource base on which agriculture depends,
- provides for basic human food and fibre needs,
- is economically viable, and
- enhances the quality of life for farmers and society as a whole.

From these definitions as well as other relevant documents on the subject, the following aspects of sustainable agriculture emerge:

i) Meeting the changing needs of today and tomorrow,

ii) Economic viability and enhanced productivity,

iii) Successful management of external and internal, and renewable and non-renewable resources,

iv) Maintenance, and preferably enhancement of the quality of environment,

v) Conservation of natural resources, particularly, soil, water and biodiversity, which form the base of agriculture.

Fig.5.2: Sustainable agriculture should help us conserve our natural resources

A system should be considered sustainable if it uses inputs, both those produced on the farm and those purchased externally, in the most efficient manner to maximize productivity and profitability while minimizing their adverse effect on environment. In other words, technology or practice, which over a period causes adverse effect on soil, water, biodiversity or climate would be considered contributing to unsustainable agriculture.

There are several parameters that characterize sustainable agriculture and we discuss some of these here.

5.3.1 Sustainability Indicators

Certain parameters related to crop yields, productivity, nutrient status, diseases as well as soil health and soil properties are referred to as **sustainability indicators**. We briefly discuss some of these.

Crop sustainability indicators (SI)

Yield: Crop yields determine agricultural production and therefore, this is an important SI. Several studies on rice-wheat cropping system done at experimental centres in India have reported a yield decline in rice (Nambiar, 1994). Of the 7 long-term rice-wheat experiments examined by Ladha et al. (2000), none had a significant decline in wheat yield, but rice yields at Pantnagar declined at a rate of 2.3% per year, while the decline at Ludhiana was 2.7% per year. Such results question the sustainability of the rice-wheat cropping system and call for ameliorative measures if this cropping system is to continue.

Factor productivity: Factor productivity is the ratio of output and input in a production system. When only one input such as fertilizer nitrogen is taken into consideration, it is termed as **partial factor productivity** (PFP) and the input indicated by a subscript. For example, PFPn is referred to as PFP for nitrogen. Yadav (1998) studied PFPn from the field experimental data for 16 years from 4 research centres in India (Pantnagar, Faizabad, Sabour and Rewa) and observed that there was a decline in PFPn in rice but not in wheat.

Kumar et al. (1998) on the other hand studied **total factor productivity** (TFP) in 3 states of India (Punjab, Haryana and Uttar Pradesh) and found that TFP during 1985-92 was lower than that in 1976-85; as a matter of fact, it was negative in Uttar Pradesh. Farmers in these 3 states have increased their fertilizer application rates over the years to obtain the same yield and this indicates a general feeling of reduced PFP due to fertilizers.

Nutrient deficiencies in crop plants: Nutrient deficiencies are good sustainability indicators, which if detected in time can save a crop and future prophylactic measures can sustain production from that crop.

Disease and pest hazards: Disease and pest hazards can sometimes make an agricultural production completely unsustainable unless ameliorative measures are immediately taken up.

Soil sustainability indicators

The quality and health of soils determine agricultural sustainability and environmental quality and as a consequence, plant, animal and human health.

Soil fertility: Soil fertility is an important SI and can be easily monitored.

Soil physical properties: Soil physical properties such as soil structure, bulk density, hydraulic conductivity and infiltration rate affect agricultural production.

Soil ecology: Soil ecology can influence organic matter dynamics, nutrient cycling, soil structure and aeration, and is an important SI.

Soil salinity and alkalinity: With increasing area under irrigation without adequate drainage, salinity/alkalinity problem is on the increase and it is becoming a serious problem in many areas of our country for sustained agricultural production.

(a) (b)

Fig.5.3: Soil and water conservation measures transform a field from (a) to (b).

5.3.2 Water

Agriculture is the biggest consumer of water worldwide. In Asia, it accounts for 86% of total annual water withdrawal. Of all the crops, irrigated rice in particular is a heavy consumer of water; it takes some 5,000 litres of water to produce 1 kg of rice. The general figures for rice and wheat are 7,650 and 4,000 m^3/ha. Projections suggest that most Asian countries will have severe water problems by the year 2025 (IRRI, 1995).

Water availability is an important index of sustainability of agriculture. In the rice-wheat belt of northern India, there are reports of serious decline in ground water and its level is receding fast. This is attributed to over-withdrawal of ground water. Such an agricultural production system is definitely not sustainable and calls for immediate measures to change it. In Unit 7, we discuss the issues related to water in detail.

5.3.3 Socio-economic Factors

Regional imbalance: Progress in agriculture has not been uniform in developing countries. An example may be taken from India of irrigation as a natural resource and input. Data on growth in irrigated area by 1966-67 and 1996-97 in different states of India shows that by 1996-97, the state of Punjab had 92.9% of its area under irrigation, followed by Haryana (76.2%) and Uttar Pradesh (68.7%). On the other hand, Maharashtra had only 14.4% area under irrigation by 1996-97 and the value for Karnataka was only 21.9%.

Although regional imbalances are unavoidable due to availability of water resources in a region, they do create a problem for a uniform sustainable agricultural production in a given country. The only option left is to develop different agricultural production systems for different states/regions, depending upon their water and soil resources so that the differences between money earned per hectare are minimized. The effort should be towards maximizing per capita agricultural income so that near uniform living standards are attained, which is a Herculean task for all developing nations and governments.

Gender equity: In several regions of these countries, hard manual labour in agriculture is left for women, while they have little role in decision-making. However, with the progress in women's education and opening of more and more job opportunities for them, this trend is on the decline. This is a welcome change. Such changes in the social system will have a definite bearing on agricultural production systems in rural areas of these countries, hopefully towards betterment.

Fig.5.4: Gender equity is a major issue in sustainable agriculture

As the perception of the term sustainability is not the same under all situations, the parameters to define and measure sustainability of an agricultural system may also vary according to local and national needs, food security scenario, socio-economic conditions of the farmers and the quality of resources. A sustainable system is one with a non-negative trend in a measured output. In other words, **a system can be considered sustainable over a defined period if the outputs do not decrease when inputs are not increased.**

Some research efforts have been made to identify and evaluate efficient sustainability parameters. Important indices that have emanated out of sporadic studies are given as under:

i) Partial factor productivity and total factor productivity;

ii) Agronomic or incremental efficiency of external inputs;

iii) Physiological or internal efficiency of external inputs;

iv) Soil quality index;

v) Sustainable yield index;

vi) Benefit-cost ratio;

vii) Soil organic matter levels; and

viii) Apparent nutrient balance sheets.

In fact, a single sustainability index that addresses productivity, resource utilization, environmental aspects and economic viability is lacking, though the same may be of immense practical significance. Unfortunately, 'sustainability' has been used merely as a fancy word by researchers, planners and policy makers. Sincere and continued efforts to understand and evaluate sustainability of an agricultural system, management practices or processes are scarce and sporadic.

SAQ 2

a) List the sustainability indicators. Which parameters of sustainability are relevant to your country's agriculture?

b) What do you understand by the term 'factor productivity'?

5.4 APPROACHES FOR SUSTAINABLE AGRICULTURE

The term 'sustainable agriculture' and 'alternative agriculture' are often used as synonyms to refer to a spectrum of farming practices which provide farmers with economically viable and environmentally sound alternatives to developing their farming systems. The sustainable or alternative agriculture should necessarily pursue the following goals:

- More thorough incorporation of natural processes such as nutrient cycles, nitrogen fixation and pest-predator relationships into the agricultural production systems,
- Reduction in the use of off-farm inputs (you will learn about these in Unit 10) having greatest potential to harm the environment or the health of farmers and consumers,
- Greater productive use of the biological and genetic potential of plant and animal species,
- Matching cropping patterns and their production potential with physical limitations of agricultural lands (this would ensure long-term sustainability of current production levels), and
- Profitable and efficient production with emphasis on improved farm management and conservation of soil, water, energy and biological resources.

Sustainable agriculture can be achieved through the following measures:

Crop Diversification: Crop diversification methods like rotation, mixed cropping, inter-cropping, double cropping have been found successful in many situations. The major advantages of these types of diversification include

- reduced erosion,
- improved soil fertility,
- minimization of risk, and
- increased yield.

Crop diversification can be done by adopting the principle of crop rotation, inclusion of crops with biological nitrogen fixation and following the practices of mixed cropping and efficient cropping systems.

(a) (b)

Fig.5.5: a) Inter-cropping; b) Mixed cropping

Choice of crops and animal components of farming system: The sustainable agricultural revolution may be triggered by shifting our mindset from a commodity-centred approach to an entire cropping or farming system. The triple goals of "more food, more income and more livelihoods" per hectare of land can be achieved provided suitable combinations of farming system components (crops, animal husbandry, forestry, fisheries, poultry agro-industries) are chosen and supported by resource based eco-technologies and farmers' participatory approach.

Genetic Diversity: Green revolution has led to genetic homogeneity with a greater genetic vulnerability to biotic stresses. Therefore, there is a need of growing crop varieties with different genetic constitutions in different agro-climatic zones. This will minimize the risk of crop failure during the insect-pest and disease attack as well as during the adverse climatic situations.

Integrated Nutrient Management (INM): INM is a principle and concept of using the different sources of nutrients like organic manures, chemical fertilizers, biological nitrogen fixation and other methods of nutrient saving in an optimum manner. Thus the productive potential of the soil can be maintained over a long period of time without adverse effects on the environment. INM also includes use of a suitable variety, optimum cultural management and soil and water use for efficient and sustainable crop production.

The important components of INM are – **fertilizers**, **farmyard manure**, **compost**, **crop residues**, **green manure**, **green leaf manure**, **rhizobium**, **blue green algae**, **phosphate solubilizing bacteria** and **azolla**.

The important steps for the adoption of INM are as follows:

i) a system approach for the management of nutrients should be followed so that input use efficiency can be increased,

ii) the recommendation of fertilizers should be based on soil test values,

iii) agronomic practices like split application of fertilizers, use of coated and granulated fertilizers, optimum combination of organic and inorganic sources of nutrients and right method of fertilizer placement should be adopted,

iv) conjunctive use of farm waste should be made,

v) nutrient responsive varieties should be selected, and

vi) appropriate water management strategies considering the right moisture nutrient interaction, should be used.

The basic concept underlying the principles of INM is the maintenance of and/or improvement of soil-fertility for sustaining crop productivity on long-term basis. This may be achieved through combined use of all possible sources of nutrition and their scientific management for optimum growth; yield and quality of different crops in their cropping systems in an integrated manner and in specific agro-ecological situations (recall Unit 2).

Organic materials were practically the only external source of nutrients to crops before the introduction of inorganic fertilizers. As a result of the advent of quick acting chemical fertilizers, a stage has reached that the supplementary and complimentary role of organic materials is being understood once again for sustainable agriculture and keeping the soil health in order. With an ever increasing cost of chemical fertilizers and their contribution to the degradation of the agricultural lands, it has been realized that organic materials such as organic manures, crop-residues, green manures, bio fertilizers and legumes in rotation, will have to be utilized judiciously to maintain and improve the soil fertility and productivity.

The manuring and recycling of various forms of residues has the advantage of converting the animal and farm wastes into useful product for meeting nutrient requirement of crops, besides maintaining the soil conditions and improving the overall ecological balance. As most parts of the plant nutrients are required by animals and human beings, if not regulated properly, enormous losses take place and substantial amount of nutrients are wasted.

Resource conservation and their regulated recycling for production is the option for sustained living.

But two basic questions remain unanswered while recommending integrated nutrient management.

i) To what extent can INM replace commercial fertilizers on field scale?

In developing countries like India, most farmers are poor and marginal and may not afford to go for a green manure crop at the cost of some economic crop in sequence. Animal manure in huge quantities may not be available to effectively contribute to the nutrient needs of the intensive cropping systems and that also when most of the cow dung is utilized as cakes to meet the domestic needs of fuel.

ii) To what extent can the use of commercial fertilizers be reduced through INM without any reduction in the targeted growth rate of food grain production to accommodate the growing needs of the increasing population of the country?

It is widely felt that in the event of a heavy cut on fertilizer use, it will be difficult to meet the growing food needs and no alternative will be left except bringing additional land under cultivation and thereby again damaging or destroying the natural ecosystem.

SAQ 3

a) What do you understand by integrated nutrient management?
b) How does integrated nutrient management affect the sustainability of agriculture?

Integrated Pest Management (IPM): IPM is a philosophy of controlling the pest in the crop field (in the context of the associated environment) by utilizing all suitable techniques and methods in as compatible a manner as possible and maintaining the pest population at levels below those causing economic injury. It deals with the optimization of different pest control practices and not the maximization of pest control in terms of overall economic, social and environmental values.

(a) (b) (c)

Fig.5.6: Practices in IPM; a) Bug trap; b) Spraying insecticide and c) Releasing ladybugs for aphid control

The important components of IPM are

- use of pest resistant or tolerant varieties,

- cultural practices like early or late planting, summer ploughing, use of pheromone traps, use of parasites, predators, and pathogens of crop pests, quarantine measures, hand collection etc.,
- judicious use of pesticides and other chemicals used for pest control.

IPM is a knowledge intensive approach and is still more of an aspiration than a reality for the average farmer in developing countries.

Sustainable Water Management: Water is an important natural resource required for crop production, human and animal need and for a number of atmospheric phenomena which are necessary for life. The necessary steps for achieving the sustainable use of water resources are as follows:

- effective water saving,
- equity in water sharing,
- efficiency in water delivery and use, maintenance and recharge of both ground and surface water resources.
- there should be an integrated policy for the conjunctive and appropriate use of rain, river, ground, sea and sewage water.


Fig.5.7: Water conservation through drip and sprinkler irrigation

Post harvest Management: Income enhancement through better management of plant produce by ensuring good transport, grading, processing is becoming popular now-a-days. Farmers will not only adopt the best available threshing, storage and processing measures but will also try to produce value added products from every part of the plant or animal.

Investment in sanitary and phytosanitary measures is important for providing quality food both for domestic consumers and for export. To assist the spread of post harvest technology awareness, governments in developing countries should make a major investment in storage, roads, transportation and on sanitary and phytosanitary measures.

Energy Management: Energy management is an important and essential input. Besides the energy efficient systems of land, water and pest management described earlier every effort will have to be made to harness biogas, biomass, solar and wind energies to the maximum extent possible. Solar and wind energy can be used in hybrid combinations with biogas for farm activities like pumping water and drying grains and other agricultural produce as you will learn in Unit 9.


(a) (b)

Fig.5.8: Alternative energies in farming; a) solar water pump; b) wind energy.

Extension of Technologies and Managing Information Input: New communication and computing technologies will have profound implications in everyday research activities. Remote sensing and other space satellite outputs are providing detailed geographic information useful for land and other natural resource management.

Programmes for extension education and communication for farmers will certainly help popularize the sustainable agricultural practices. A very important option in extension techniques towards sustainable agriculture is "Social Engineering" which means influencing the farmers' attitude to make them aware about ecological production and economic consequences of a technology and policy being adopted. This can make all the above components successful at a farmer's field level.

Decision Support System (DSS): The decision support systems (DSS) involving simulation modelling comprises of studying simultaneously the soil-plant-environment continuum. Once an appropriate model is developed and validated under a defined farming situation, sustainability of a management practice or practices can be evaluated even without long term experiments (LTEs) under similar situations. The data of existing LTEs can also be used for deriving useful predictions and trends on sustainability of production systems. The weather data, genetic coefficients of the crops and soil parameters as per requirements of the DSS models usually suffice.

The major problem with this approach is that modelling of biological systems is still in its infancy. Whichever models are developed, their success and reliability of simulation depend on the quality and the amount of minimum data set generated to validate and run the models. Nevertheless, there is a great scope to develop and improve the simulation models for their use in sustainability analysis. Majority of the existing models are meant for simulation of crop growth and nutrient dynamics in soil-plant system under given set of environmental conditions. There should be an effort to include, if possible, an economics sub-routine in existing models, or develop new models with capability to simulate economic viability besides crop growth and other parameters.

We now summarise what you have studied in this unit.

5.5 SUMMARY

- **Sustainability of agriculture** in developing countries is believed to be at stake for three major reasons that emerged as a consequence of intensive farming:

  - excessive use of irrigation water,
  - replacement of rich diversity of traditional varieties with fewer high yielding varieties, and
  - indiscriminate use of fertilizers and pesticides.

- As the per capita availability of agricultural land in these countries is further shrinking, sustainable agricultural productivity has to be thought about in terms of raising yield levels until population stabilizes and malnutrition is alleviated. Here **sustainable productivity implies a reasonable level of production without harming the ecosystem.**

- In order to realize sustainable agriculture, it is important **to maintain soil health and quality, practice scientific principles of crop rotation, maximize benefits**

from natural nutrient cycles of flows, minimise soil loss and protect ground waters from contamination.

- Though considerable improvement in productivity has so far come from greater use of energy, chemicals, water and machinery, the alternative route for achieving the goal without harming the long-term productive potential of soil exist in adoption of **sustainable agricultural strategies**. Research on restoration ecology and intensification of agriculture in inter-connectivity with animal husbandry, forestry, plantation, horticulture, fisheries and other agricultural enterprises requires much more support.

5.6 TERMINAL QUESTIONS

1. What do you understand by sustainability?
2. Describe the reasons for unsustainability in agricultural practices in your area.
3. What are the parameters and goals of sustainable agriculture?
4. Discuss the approaches of sustainable agriculture.

REFERENCES

1. Adams, W.H., Bourn, N.A.D. and Hodge, I. (1992) Conservation in the wider country side. *Land Use Policy* **41**: 235-247.
2. FAO (1989) Sustainable Agricultural Production – Implications for International Agricultural Research. *Research and Technology Paper* **4**, FAO, Rome, 152 p.
3. Giampietiro, M., Corretelli, G. and Pimentel, D. (1992) Agricultural analysis of agricultural ecosystem management, human return and sustainability. *Agricultural Ecosystem & Environment* **38**: 219-244.
4. IRRI (1995) Water – A Looking Crisis, International Rice Research Institute, Los Banos, Philippines. pp. 90.
5. Janvry, A. de and Garcia, R. (1988) Rural poverty and environmental degradation in Latin America: causes, effects and alternative solution. Paper presented at the *International Consultation on Environment, Sustainable Development and the Role of Small Farmers.* International Funds for Agricultural Development, Rome.
6. Kumar, P., Joshi, P.K., Johansen, C. and Asokan, M. (1998) Sustainability of rice-wheat based cropping system in India. *Economic and Political Weekly* **33**:A 182-188.
7. Ladha, J.K., Fischer, K.S., Hossain, M., Hobbs, P.R. and Hardy, B. (2000) Improving the productivity and sustainability of rice-wheat systems of the Indo-Gangetic plains: a synthesis of NARS-IARI partnership research. *IRRI Discussion Paper Series No. 40*, 31p. International Rice Research Institute, Makati City, Philippines.
8. Nambiar, K.K.M. (1994) *Soil Fertility and Crop Productivity under Long-Term Fertilizer Use in India.* 144p. Indian Council of Agricultural Research, New Delhi.
9. Yadav, R.L. (1998) Factor productivity trends in a rice-wheat cropping system under long-term use of chemical fertilizers. *Experimental Agriculture* **34**: 1-18.