1 INTRODUCTION

1.1. SUSTAINABLE AGRICULTURE: DEFINITIONS AND GOALS

The sustainability of agricultural production is a question of major concern for the human race because agriculture is the prime source of food for an increasing world population. Most projections indicate that world population will approximately double within another generation or two, making the task of approximately doubling food production with our finite resources even more critical. This task must be accomplished in a sustainable manner.

Maintenance and management of soil fertility is central to the development of sustainable food production systems. Sustainability is dependent to a large degree on recycling, to the extent possible, the inputs into a production system, thereby increasing efficiency of output per unit of resource input. The discipline of soil fertility defines and outlines the mechanisms by which nutrients contained in these inputs are transformed, made available to crops, and cycled through the production system. Thus the principles that regulate soil fertility are fundamental to the philosophy of sustainability.

Rodale (1988) has enumerated the following reasons for the current interest in sustainability in agricultural production:

1. Because nonrenewable resources are the basis of operation and productivity of modern (American) agriculture, it is feared that when these nonrenewable resources are depleted, either food will become too expensive or productivity will decline.
2. The high level of production today contributes to environmental pollution in terms of soil erosion, degradation, and deforestation.
3. The escalation of pollution problems is often traceable to some agricultural practices.
4. There is concern about finding ways to rely more on internal farm resources and continuously enhancing them under rapid population growth and increasing pressures on the limited resources available.

5. It is likely that conventional technologies and agricultural production systems will be unsustainable in the future if agricultural production becomes the main source of energy and feed stocks.
6. There is the problem of whether the good life in rural areas can be maintained if family farms are replaced by large-scale industrialized farms that produce all the food.

The Board for International Food and Agricultural Development (BIFAD, 1988) task force gave the following definitions of sustainable agriculture, as developed by different sources:

1. The successful management of resources for agriculture to satisfy changing human needs, while maintaining or enhancing the natural resource base and avoiding environmental degradation.
2. The ability of an agricultural system to maintain production over time in the face of social and economic pressures.
3. One that should conserve and protect natural resources and allow for long-term economic growth by managing all exploited resources for sustainable yields.

Okigbo (1991) after analyzing the various definitions of sustainable agriculture put forth by various workers (Dover and Talbot, 1987; Knezek et al., 1988; Lynam and Hezdt, 1988) defined a sustainable agricultural production system as one that maintains an acceptable and increasing level of productivity that satisfies prevailing needs and is continuously adapted to meet the future needs for increasing the carrying capacity of the resource base and other worthwhile human needs. Sustainability can only by achieved when resources, inputs, and technologies are within the capabilities of the farmer to own, hire, and manage with increasing efficiency to achieve desirable levels of productivity in perpetuity with minimal or no adverse effects on resource base, human life, and environmental quality.

An agricultural production system is location specific, and it is uniquely determined on the basis of interacting physiochemical (soil, climate, radiation etc.), biological (crops, weeds, pests, beneficial organisms, etc.), managerial, and socioeconomic elements that satisfy specific objectives.

Croplands provide about 80% and range and fisheries 10% each of the total world food production (Swaminathan, 1986). Thus the soil has to bear most of the burden of production to meet world food needs. The estimate of the global food deficit by the International Food Policy Research Institute for the year 2000 A.D. is approximately 70 million Mg yr^{-1}. Thus even with all the advances made in agricultural sciences, millions of people may remain hungry by the end of the twentieth century. The question of sustainability therefore is of paramount importance. It should be recognized, however, that most often hunger results from political and social instability rather than from inability to produce food.

1.2. FACTORS DETERMINING SUSTAINABILITY

Of a large number of factors determining sustainability of agriculture in a region, population pressures and the availability of arable land are the most important. Population growth during 1963 to 1971 in North America, Europe, Latin America, Africa, and South Asia was 1.3, 0.8, 2.9, 2.9, and 2.8% yr^{-1}, respectively (United Nations, 1972). The population increase in developing countries in Asia, Africa, and South America between 1986 and 2000 A.D. will contribute to about 90% of the total global population increase (Population Reference Bureau, 1986). Also, the population percentage depending on agriculture as a livelihood in developing countries is much larger than in developed countries; in 1990 it was 68.3% in Africa, 63.6% in Southeast Asia, and 26.1% in Latin America as compared with 9.3% in Europe and 2.4% in North America. Despite such a large percentage of the population working in agriculture in developing countries, 12.5 million tons of cereals were provided to them in 1990 under World Food Program (1991). Regarding the availability of arable land, there is a possibility of cultivating an additional 200 million ha in North America, 290 million ha in South America, and 340 million ha in Africa, but little in Europe and Southeast Asia (Revelle, 1976; Buringh, 1981; Dudal, 1982; Lal and Stewart, 1992).

Considering population pressure and availability of arable land, the world can be classified under four classes as given below:

Class I. Regions having low population pressure and abundant per capita arable land such as North America and Oceania.
Class II. Regions having low population pressure but a shortage of per capita arable land such as Europe.
Class III. Regions having high population pressure and abundant per capita arable land such as Africa and South America.
Class IV. Regions having high population pressure and low per capita arable land such as Southeast Asia.

Sustainable agricultural practices would be different in different regions. In Class I areas, one can consider plans involving reduced use of fertilizers, pesticides, and other agricultural chemicals and greater dependence on natural resources such as organics — including legumes in rotation, use of farm waste as manure, and related practices. Sustainable agricultural plans for Class IV regions cannot avoid increased application of fertilizers, pesticides, and other manufactured inputs, despite using organic manures, green manuring, inclusion of legumes in crop rotation, and other resource-conserving practices.

1.3. SOIL FERTILITY

Whether the land is plentiful or in short supply, efficient soil fertility management is the key to sustainable agriculture.

Soil fertility research and management is primarily concerned with the essential plant nutrients—their amounts, availability to crop plants, chemical reactions that they undergo in soil, loss mechanisms, processes making them unavailable or less available to crop plants, and ways and means of replenishing them in these soils.

The objective of this text is to discuss various aspects of soil fertility management for a sustainable agriculture. We discuss the nutrient transformations that occur in the soil and how various management practices may be used to regulate and control these transformations. Special emphasis is placed on heavily populated, developing nations of the world, where the pressure on land is the greatest and the sustainability of prevailing agricultural systems is posing a serious problem.

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