SUSTAINABLE FOOD AND WATER SECURITY

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1. Introduction

It is widely agreed that the breathing spell provided by the green revolution for achieving a balance between population growth and food production will soon get exhausted, unless we take steps to foster an ever-green revolution based on principles of ecology, gender and social equity, economics, employment generation and energy conservation. Will the twenty-first century be one of hope or despair on the food front? Will there be enough water for human, agricultural, industrial and ecosystem needs? I would like to deal with these critical questions in the following four parts:

- Food security;
- Water security;
- Climate management;
- Safeguarding the ecological foundations of sustainable agriculture: agrobiodiversity.

The present global trends in the areas of preventing adverse changes in climate and sea level and in the protection of the ecological foundations for sustainable agriculture are not encouraging. However, there is still a chance for achieving the goals of "food and drinking water for all" in the coming century, because of the uncommon opportunities opened up by science and technology. This paper describes some of the emerging challenges and opportunities.

2. Food Security

The concept of food security has been undergoing refinement during the last 50 years. Immediately after World War II, food security meant building emergency grain reserves and ensuring the physical availability of food in the market. After the onset of the green revolution in the late sixties, it became obvious that economic access to food is equally important for ensuring food security at the household level. During the eighties, it became evident that the gender dimension of food security should receive attention, in view of the growing feminization of poverty and agriculture. This was highlighted at the World Conference on Women held at Beijing in 1995. The principle of social access, with reference to women and marginalized communities was hence added to the concept of food security. Finally, after the UN Conference on Environment and Development held at Rio-de-Janeiro in 1992, there has been an increasing understanding of the role of environmental factors in food security. The ecological foundations essential for sustained agricultural progress are increasingly under stress due to human activities. Agenda 21 of UNCED addresses these concerns. Without safe drinking water and environmental hygiene, the biological absorption and retention of food will be poor. Thus, environmental access to food becomes important.

Based on the above considerations, the Science Academies Summit held in July 1996 at the M. S. Swaminathan Research Foundation, Madras, India, in preparation for the World Food Summit convened by FAO in Rome in November 1996, proposed the following comprehensive definition of food security.

Policies and technologies for Sustainable Food Security should ensure:

- That every individual has the physical, economic, social and environmental access to a balanced diet that includes the necessary macro- and micro-nutrients, safe drinking water,sanitation, environmental hygiene, primary health care and education so as to lead a healthy and productive life;
- That food originates from efficient and environmentally benign production technologies that conserve and enhance the natural resource base of crops, animal husbandry, forestry, inland and marine fisheries.

The term “green revolution” was coined in 1968 by Dr William Gaud of the U.S. Agency for International Development to highlight the opportunities opened up by the semi-dwarf varieties of wheat and rice to increase production through higher productivity. 1968 was also the year when the Government issued a special postage stamp to commemorate India’s wheat revolution (Swaminathan, 1993). Early in January 1968, I made the following statement in my Presidential address to the Agricultural Sciences section of the Indian Science Congress (Swaminathan, 1968).

Exploitive agriculture offers great possibilities if carried out in a scientific way, but poses great dangers if carried out with only an immediate profit motive. The emerging exploitive farming community in India should become aware of this. Intensive cultivation of land without conservation of soil fertility and soil structure would lead, ultimately, to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water will lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high-yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops. Therefore the initiation of exploitive agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture, and without first building up a proper scientific and training base to sustain it, may only lead us, in the long run, into an era of agricultural disaster rather than one of agricultural prosperity.

Thus in the same year when the term green revolution first came into use, I had stressed the need for concurrent attention to productivity improvement and the conservation of the ecological foundations essential for sustainable advances in agricultural productivity. I pointed out that such an integrated approach is the pathway to an ever-green revolution or sustained progress in enhancing yield per ha. (Swaminathan, 1996).

Since the term sustainable agriculture is now widely used, it may be appropriate to recall what Varro, a Roman landowner, said in first century BC:

Agriculture is a science which teaches us what crops should be planted in each kind of soil, and what operations are to be carried on, in order that the land may produce the highest yields in perpetuity.

Varro was probably the earliest to define what we now call “sustainable agriculture.”

In the coming century, we will have to produce more food and other agricultural commodities under conditions of diminishing per capita arable land and irrigation water resources and expanding biotic and abiotic stresses. However, it is obvious that the pathway for productivity enhancement has to be different from that associated with the “green revolution.” It is equally important that agriculture should help developing countries not only to produce enough food for the growing population but should also lead to the generation of more income and opportunities for skilled employment. How can we develop agriculture into an effective instrument for creating more income, jobs and food?

2.1 Integrated Farming Systems

These triple goals can be achieved if we develop and disseminate ecologically, economically and socially sustainable integrated farming systems (IFS). The seven pillars of IFS are the following:

2.1.1 Soil Health Care

This is fundamental to sustainable intensification, IFS fosters the inclusion of stem nodulating legumes like *Sesbania rostrata*, incorporation of *Azolla*, blue-green algae, and other sources of symbiotic and non-symbiotic nitrogen fixation and promotion of cereal–legume rotation in the farming system. In addition, vermiculture composting and organic recycling constitute essential components of IFS. IFS farmers are trained to maintain a Soil Health Card to monitor the impact of farming systems on the physical, chemical and microbiological components of soil fertility. Also, in many tropical countries, crop-livestock integrated farming systems help to conserve soil fertility.

2.1.2 Water Harvesting and Management

IFS farm families include in their agronomic practices measures to harvest and conserve rain water, so that it can be used in a conjunctive manner with other sources of water. Where water is the major constraint, technologies which can help to optimize income and jobs from every liter of water are chosen and adopted. Maximum emphasis is placed on on-farm water use efficiency and on the use of techniques such as drip irrigation, which help to optimize the benefits from the available water.

2.1.3 Crop and Pest Management

Integrated Nutrient Supply (INS) and Integrated Pest Management (IPM) systems form important components of IFS. The precise composition of the INS and IPM systems will depend on the components of a farming system as well as on the agro-ecological and soil conditions of the area. Computer aided extension systems will provide farm families with timely and precise information on all aspects of land, water, pest and post-harvest management.

2.1.4 Energy Management

Energy 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.

2.1.5 Post-harvest Management

IFS 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. Post harvest technology assumes particular importance in the case of perishable commodities like fruits, vegetables, milk, meat, egg, fish and other animal products and processed food. A mismatch between production and post-harvest technologies affects adversely both producers and consumers. Growing urbanization leads to a diversification of food habits. Therefore there will be increasing demand for animal products like milk, cheese, eggs as well as for fruits, vegetables and processed food. Agro-processing industries can be promoted on the basis of an assessment of consumer demand. Such food processing industries should be promoted in villages in order to increase employment opportunities for rural youth. In addition, they can help to mitigate micronutrient deficiencies in the diet. A well planned urban green belt movement around towns and cities will help to improve both human and animal nutrition and the environment.

Investment in sanitary and phytosanitary measures is important for providing quality food both for domestic consumers and for export. To assist the spread of IIFS, Governments should make a major investment in storage, roads, transportation and on sanitary and phytosanitary measures. ISO–9000 and ISO–14000 standards of environmental management should be popularized.

2.1.6 Choice of the Crop and Animal Components of Farming Systems

In IFS, it is important to give very careful consideration to the composition of the farming system. Soil conditions, water availability, agro-climatic features, home needs and above all, marketing opportunities will have to determine the choice of crops, crop varieties, farm animals and aquaculture systems. Small and large ruminants will have a particular advantage among farm animals since they can live largely on crop biomass. Backyard poultry farming can help to provide supplementary income and nutrition.

2.1.7 Information, Skill, Organization, Management, and Marketing Empowerment

IFS is based on the principle of precision farming. Hence, for its success, IFS system needs a meaningful and effective knowledge and skill empowerment system. Decentralized production systems will have to be supported by a few key centralized services, such as the supply of credit, seeds, biopesticides, and animal disease diagnostics. Ideally, an Information Shop will be set up by trained local youth in order to give farm families timely information on meteorological, management, and marketing factors. Organization and management are key elements and depending on the area and farming system, steps will have to be taken to provide to small producers the advantages of scale in processing and marketing.

IFS is best developed through participatory research between scientists and farm families. This will help to ensure economic viability, environmental sustainability and social and gender equity in IFS villages. The starting point is to learn from families who have already developed successful IFS procedures.

It should be emphasized that IFS will succeed only if it is a human-centered rather than a mere technology-driven program. The essence of IFS is the symbiotic partnership between farming families and their natural resource endowments of land, water, forests, flora, fauna and sunlight. Without appropriate public policy support in areas like land reform, security of tenure, credit supply, rural infrastructure, input and output pricing and marketing, small farm families will find it difficult to adopt IFS.

Class of objectives		
Agricultural	1	maximize soil productivity
	2	minimize costs of agricultural production
Socioeconomic	3	maximize total employment in agriculture
	4	minimize regional decrease in employment in agriculture
Environmental	5	minimize input of nutrients per unit of acreage
	6	minimize input of nutrients per unit of product
	7	minimize input of pesticides per unit of acreage
	8	minimize input of pesticides per unit of product

Table 1: Objectives used in the general optimal allocation of land-use computer model (Rabbinge and Van Latesteijn, 1992)

In the U.S.A., intensive research and testing of Low External Input Sustainable Agricultural Practices (LEISA) are in progress. Under a project supported by the European Union, a computer model, GOAL (General Optimal Allocation of Land Use) has been developed, which calculates optimal land use in the Community of the 12 member states. The objectives incorporated in the GOAL model are shown in Table 1.
Table 1. Objectives used in the general optimal allocation of the land-use computer model (Rabbinge and Van Latesteijn, 1992)

Most land use trends indicate that there will be a dramatic decrease in farmland. About one third of the present area under cultivation will be sufficient once productivity in the EC reaches the optimum. Similarly studies at the International Water Management Institute (IIMI) have shown that nearly 50% of the additional irrigation water required by 2025 can be met by improved efficiency of irrigation. Our first aim should be to eliminate the widely prevalent yield gap (i.e. gap between potential and actual yields in farmers' fields) with the best currently available technologies through appropriate packages of technology, services and public policies.

2.2 Meeting the Challenge

How can we meet these challenges? As we approach the new century and millennium we are experiencing three major revolutions in science and technology, which will influence agricultural technology in a fundamental manner. It will therefore be appropriate to make a brief reference to them. Three major scientific revolutions are underway:

1. The gene revolution—which provides a molecular understanding of the genetic basis of living organisms, as well as the ability to use this understanding to develop new processes and products for agriculture, the environment, and for human and animal health;
2. The information and communications revolution—which allows a very rapid growth in the systematic assimilation and dissemination of relevant and timely information, as well as a dramatically improved ability to access the universe of knowledge and communicate through low cost electronic networks; and
3. The ecotechnology revolution—which promotes the blending of the best in traditional knowledge and technology with modern science.

In principle, these three types of advances—when coupled with improvements in management science and governance—greatly increase the power of a scientific approach to genetic improvement, agronomics, the integrated management of natural resources and ecosystems, and the management of local and regional development policies. However, these scientific revolutions seem to be proceeding at an ever-increasing pace, with most of the action occurring in a few places in industrialized nations. Developing countries should lose no further time in harnessing these technologies for achieving the twin goals of natural resources conservation and food security.

2.3 The Gene Revolution

The past ten years have seen dramatic advances in our understanding of how biological organisms function at the molecular level, as well as in our abilities to analyze, understand, and manipulate DNA molecules, the biological material from which the genes in all organisms are made. The entire process has been accelerated by the Human Genome Project, which has poured substantial resources into the development of new technologies for working with human genes. The same technologies are directly applicable to all other organisms, including plants. Thus, a new scientific discipline of genomics has arisen. This discipline has contributed to powerful new approaches that can be used in agriculture as well as in medicine and has helped to promote the biotechnology industry.

Several large corporations in Europe and the United States have made major investments in adapting these technologies to produce new plant varieties of agricultural importance for large-scale commercial agriculture. The same technologies have equally important potential applications for addressing food security in the developing world.

The key technological developments in this area are:

- Genomics: the molecular characterization of species;
- Bioinformatics: data banks and data processing for genomic analysis;
- Transformation: introduction of individual genes conferring potentially useful traits into plants, trees, livestock, and fish species;
- Molecular breeding: identification and evaluation of useful traits by use of marker assisted selection, which greatly speeds up traditional breeding processes;
- Diagnostics: identification of pathogens by molecular characterization;
- Vaccine technology: use of modern immunology to develop recombinant dna vaccines for improved disease control against lethal diseases of animals and fish.

Developing countries must exploit these techniques and develop partnerships with advanced research institutions for this purpose. There are widespread public concerns about the potential adverse impact of genetically modified organisms (GMOs) on human health and the environment.

Some of these concerns are genuine. To take advantage of recombinant DNA technologies without associated harm to human or ecological health, it is important that every country has in place suitable institutional structures and regulations for biosafety, bioethics, and biosurveillance. A recent statement issued by the Royal Society of London on “Genetically modified plants for food use” provides guidelines for the safe handling of biotechnological applications (Royal Society, 1998).

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