Sustainable Crop Production in Developing Countries: A Daunting Challenge Ahead

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Knowledge and experience available today can be strategically harnessed to develop a new agriculture paradigm that should ensure the needed high yields while alleviating or minimizing the negative aspects of agriculture.

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Executive Summary

India is the second populous country in the world, after China, with current population of around 1.2 billion. Growing population is causing a progressive stress on all the services (including those from food production sector) required to maintain this population. Like other industries, agriculture (involving crop, animal and fish production) also causes pollution (much of it from fertilizers and pesticides) besides issues of land degradations and loss of biodiversity. The need for more food production in future should not necessarily mean more pollution and deterioration of natural resources leading to negative effects on agriculture production. Knowledge and experience available today can be strategically harnessed to develop a new agriculture paradigm that should ensure the needed high yields while alleviating or minimizing the negative aspects of agriculture. Authors of this article have shared their views on this new paradigm and the required shift in the way we are producing crops at present.

INTRODUCTION

Sustainable crop production involves the successful management of agriculture resources to meet the changing human needs, while maintaining or enhancing the environment quality and conserving natural resources (TAC, CGIAR, 1988). The natural resources of a country are its most valued endowment, on which all life depends in most countries of the world. In the recent past, with the burgeoning populations and the national goals of seeking self-sufficiency in food production, the natural resource base is being depleted gradually. The net result is human-induced degradation of land and water resources through inadvertent, inappropriate use of technological innovations. The global economic cost of human-induced soil erosion was estimated to be US $ 400 billion per year. Even in a country like the United States, the top soil in about 2.5 billion hectares is being lost annually with an economic cost of off-site damage of about 44 billion dollars (Lal, 1998). Few estimates of the concomitant loss of soil fertility are available. For example in Zimbabwe, a Food and Agriculture Organization (FAO) study indicated that on an average, 1.6 million tonnes of nitrogen and 0.24 million tonnes of phosphorus are lost per year through erosion, and the cost to replace these nutrients would exceed US $ 1.5 billion (Stocking, 1986). Most countries cannot afford such high costs for maintenance of their agricultural sector. When degradation becomes a continuing process, the yields decline and the farmer is forced to move out to eke a living at another piece of land, which in most instances may represent a fragile ecosystem—steep lands or coastal swamps—as much of the better arable land is already under cultivation. The system then goes through a downward spiral to the detriment of all.

The dilemma today is to reduce this vicious cycle of events by trying to conserve the land resource base while at the same time, use it sustainably to feed and clothe the growing population. These are the basic tenets of sustainable agriculture, which present immense practical problems to their proper implementation, particularly in developing countries. In this paper we share our perspectives of sustaining crop production, as a component of agriculture production (that also includes animal and fish production).

CONSTRAINTS TO SUSTAINABLE CROP PRODUCTION

Land Degradation

The problem of land degradation clearly emerges as the most significant threat to agriculture in developing countries, especially in the tropics. The most critical sustainability issue is the prevention of unsustainable land use, wherein the central issue is the conversion of land use from perennial crops to annual crops. This conversion is happening at both ends of the rainfall regime. At the wet end, tropical forest gets converted into annual crop areas, such as maize. At the dry end, perennial grasses get converted into annual crops, such as millets and sorghums.

Land related constraints could be grouped in two basic categories: intrinsic and induced factors. Intrinsic factors are the parent materials of soils; – chemical, physical and biological conditions that are inherent properties of the land. Examples are nutrient deficiencies, shallow soil depth, and low organic carbon content. Induced factors, on the other hand, are caused by external phenomena, mainly climate and human activity, and include moisture stress, soil compaction, and soil erosion. Some combination of soil erosion, deterioration of structure, loss of nutrients, build up of salts and other toxic elements, water logging and aridification are leading to decline in the biological activity of the soil in most agricultural systems of the developing world. This threat needs addressing through mobilization and integration of knowledge for scientific land use planning that utilizes digital information technology; a shift in research imperatives to future-oriented issues, such as identification of indices of sustainable land management, and the long-term on-site and off-site consequences of agricultural practices. These should be done involving communities and farmers to address local needs of an area, and to ensure that the new practices are owned and followed by all.

Loss of Biodiversity

Traditionally, farmers have always selected crops and plants within each of the crop species that had valuable characteristics. The continuous selection over generations of farmers has resulted in what are called farmers' varieties or landraces. Landraces and their wild relatives contain genetic traits, such as pest resistance or heat tolerance, needed by farmers for cultivation and for plant breeders to use these to incorporate useful traits in other varieties. However, many factors, including human pressures, are causing the disappearance of valuable genetic resources. The extensive commercial monoculture of crops has led to decrease in the mixed and intercropping systems that were more resistant and provided stability of production and ensured balanced diets to the farming families. The monoculture has reduced crop diversity (both within a species and between crop species) leading to uniformity of genetic material. Genetic uniformity makes food crops vulnerable to external stresses such as pest and disease outbreaks. For example, in the United States, maize blight destroyed almost US$1 billion worth of maize in 1970. High yielding varieties of crops will still be required, but the improvement programmes should ensure broad genetic base of their material and retain and promote high yielding landraces.

Climatic Variability and Change

There has been some concern among agricultural scientists about the change in rainfall patterns in an adverse direction in some parts of the world. An example is the Sahelian Zone of West Africa. Decreasing rainfall and devastating, recurring droughts in this region are related to climatic changes. Decrease in rainfall and persistent droughts, leading to desertification have dire consequences for sustainability of agriculture in the fragile environments. As rainfall decreases, risks associated with cultivation of crops increases. Stabilizing production of agricultural commodities in these low rainfall environments is not only a question of sustainability of agriculture but also sustainability of human societies associated with them. Stabilizing the production, by decreasing year-to-year yield fluctuations, in low rainfall zones is the clearest way of achieving sustainability of agriculture. This could be achieved by a host of methods—breeding short-duration, and drought tolerant varieties, using crops with high water and nutrient use efficiencies, better crop residue management and other measures aimed at improved rain water management (for example, the community-based watersheds) for escaping the risks associated with variable rainfall.

Resilience of High Productive Systems

The production systems for irrigated rice and wheat that have long been regarded as the most visible success are also examples of high-input production systems. Maintaining their productivity is important for the world's supply of food. The total factor productivity (total output index divided by total input index) of rice-wheat cropping system which accounts for 90% (12 m ha) in South Asia has recently reduced to a level of –0.4 (from 2.9 in 1976-85) indicating that inputs have ceased increasing the yield growth (Kumar *et al.*, 2000). In simple terms, to produce a quantity of yield if a farmer was applying 'X' kg of inputs (largely fertilizer) say in 1990, today he/she has to apply "X+" to harvest the same yield. Crop residues such as rice and wheat straw that were being recycled as animal feed (say in the 1970's) are burnt at present because these are in excess of demand as feed. Punjab state alone burns 12 million tonne of rice and wheat straw, and with it urea worth 61.73 crore is lost every year (Sidhu *et al.* 1998). All crop residues can be composted into manure, which is an important source of crop nutrients and thus will return the crop residues to field instead of burning to sustain productivity of these systems. The method of composting could be set-up as a village level enterprise also (Rupela *et al.* 2001).

Pests and Diseases

The introduction of high-input systems in crop production has brought about a marked change in the status of pest and disease complexes that affect crops. Crop pests have become a major constraint in sustainable crop production. According to Razak (1993), about 10-20% of the crops are lost annually in India, both in the field as well as during storage, which amounts to more than Rs. 6000 crores. The use of synthetic pesticides has undoubtedly played a key role in increasing crop production. However, their use has to be optimized keeping in view the safety to producers and consumers as well as environmental pollution by over-use of chemical pesticides. Indiscriminate use of pesticides has led to the accumulation of toxic hazards through pesticide residues in the food chain (Osfor *et al.*, 1998). It has been reported that the number of insects which exhibited resistance to pesticides was seven in 1935; swelled to 462 in 1986 and are on the rise world wide. Several insecticides are also known to induce the resurgence of pests on crops (Dhaliwal and Singh 2000; Ito and Nakata 1999).

Integrated pest management (IPM) has a key role to play in sustainable crop production. Many ecologically based IPM practices have been developed to reduce the loss caused by pests (Jayaraj *et al.*, 1988; Luck *et al.*, 1998). Results of case studies in six developing countries assembled by the World Resources Institute (Thrupp 1996) suggested that biodiversity based crop production (involves use of biopesticide and other practices of alternative agriculture) resulted in increased yield and returns. The concept of IPM for sustainable crop production must be given higher emphasis in the developing countries; research efforts on developing ecologically stable and economically viable pest management strategies particularly in stressed environments and for resource poor farmers need further emphasis.

Converting Challenges into Opportunities of the Future

Experience of the past plus an assessment of future needs to achieve sustainable agricultural development suggests following major opportunities.

Firstly, because of unparalleled increase in human populations in the developing countries, future increases in food production must even exceed those of the past three decades. More than 90 million people are being added each year, a billion a decade. We cannot expect a repeat of the massive increases in irrigation and fertilizer use that characterized crop production in the last 30 years (Brown, 1993). Except in Africa, the economics of increases in the use of these inputs began to decline in the mid-1980s and are not likely to increase in the decades ahead. The expanded food needs must be met without great expansion in the area under cultivation. Most highly productive lands are already farmed and environmentalists will firmly resist further clearing of forests and grasslands for crop production. It is not likely that more than 25% of the expanded food needs will come from newly cleared lands (Crosson and Anderson, 1992). The added production must come primarily from increases in yields per hectare, but in a way that is sustainable on a long term.

The green revolution during 1960's and 1970s radically reshaped agricultural production in some developing countries. In less than a decade, these countries went from famine to feast. This has, however, left some scars or second generation problems. The major issue is the inappropriate use of chemical fertilizers and pesticides in particular and need to be addressed. Also, the green revolution delivered benefits mainly to more favorable agro-ecozones having ample water and capital resources. It has bypassed the dry land cropping areas. Despite the green revolution, there are still about 840 million people, or 13% of the global population, who are food insecure, mostly living in the dry areas or the semi-arid tropics (Dar, 2001). Therefore, the challenge now is to move the green revolution into ecologies, systems, and population that have not benefited significantly from technological advances. This means improved technologies and systems, for areas less endowed with water and productive soils and gaining a better understanding of the poor people in these areas, the cultures and community structures. It means policy changes that will permit low-income people to share the benefits of these new technologies and systems (McLure 1988; Pathak and Kothari 1998) and learning how their lives can be improved.

The next challenge for the research community is to create a new way of thinking about marginal areas and how the adversities of these areas could be turned into advantages. A recent study by the Asian Development Bank (2000) concluded that "Investments in infrastructure, agricultural technology and human capital are now at least as productive in many rainfed areas as in irrigated areas and have a much greater impact on poverty alleviation". The green revolution crops (rice and wheat) depended on farmers having access to favorable environments to avoid any moisture or nutrient stress. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is promoting a new concept to enhance sustainable crop production in the dry lands. The concept states that great productivity gains can be made by adapting the crop to the environment, through better stress, disease, and pest resistance or avoidance. This way productivity can be enhanced and catalyzed ushering a "Grey to Green Revolution "(Dar 2001). Many policy makers were also concerned about the gender impacts of the green revolution—that the beneficiaries were men, not the women and the children who depend on them. Women are especially disadvantaged in the dry areas. Nonetheless, the grey to green revolution holds special potential to help poor women

To couple food production efforts with those that enhance environmental quality is another challenge. This coupling is essential first of all for the developing countries, which depend upon their natural resources to underpin food production. It is also essential to initiate steps to reduce environmental contamination and natural resource destruction. Every effort should be made to find ways to establish "win-win" systems that will provide increased food production and better environment. In agriculture there are some good examples of such systems that are on the horizon (El-Ashry 1993; Maredia *et al.* 2000).

Crop production technologies that involve incorporation of crop residues (for recycling of nutrients), use of intercropping systems including agro-forestry, and combinations of cereals and legumes will contribute to the sustainability of low-input agriculture. Similarly, the development of crop varieties tolerant to environmental stresses and to pest and diseases will be environment-friendly and cheaper and easier for the farmers to adopt. The use of farming systems approach with holistic management of natural resources at a farm should be more sustainable, and there are emerging examples. A farmer in Punjab has setup an excellent system of recycling natural resources at his farm. Like most farmers in Punjab he uses crop residues as cattle feed and uses their dung for composting and returns the manure to field. In addition, he uses press-mud (from sugar factory) as part of total feeds for his cattle and pigs; the waste from poultry and piggery (on the edges of a fish pond) serves as fish meal;. and the nutrient rich water from the fish pond is used for irrigating crops. Fish yields at this farm are the highest in the region. His crop yields are marginally higher (while his inputs significantly lower) than his neighbors. While most farmers in Punjab burn rice-straw, he incorporates it in soil to maintain soil health.

However, the major challenge is to introduce community-based soil and water management technologies on-farm to achieve increases in productivity and, at the same time, reduce soil erosion. The rural poor, who constitute a majority of the small land holders – people who often lack the simple necessities of life—may not be willing to undertake such conservation related practices. Community or group action of farmers is necessary to effect these changes. External financial investment and technical support, either by governments, financial institutions and NGOs will be needed. Only when poor farmers have increased their incomes and the principle of shared cost of conservation is adopted and applied will there be any hope for soil and water conservation programmes.

An example is the ICRISAT-led "Participatory Consortium approach for natural resource management in watersheds" in collaboration with the Govt. of Andhra Pradesh, Central Research Institute for Dryland Agriculture (CRIDA), Acharya N. G. Ranga Agricultural University (ANGRAU) and several NGOs. The consortium model was developed to link strategic research with developmental research to enhance technology adoption for increasing productivity, managing natural resources, and improving livelihoods of the poor people in less-endowed, dry areas. The approach involves harnessing the strengths of consortium partners for the benefit of the stakeholders. The process involves participatory, bottom-up approach to identify problems, possible solutions and approaches. Site specific solutions are derived by refining the existing technologies. The stakeholders (farmers, including women) are empowered to take appropriate decisions and implement the problems and manage the processes. In the Adarsha Watershed of Kothapally, Ranga Reddy district, Andhra Pradesh, the farmers have been able to: (i) increase crop productivity by two to three fold, (ii) increased income and livelihood opportunities through training, (iii) reduced run-off and soil loss, and (iv) increased ground water recharge and thus increased water availability in watersheds (Wani *et al*, 2002). This model is now being outscaled to more than 50 watersheds in Andhra Pradesh.

Smallholder farmers and other rural people depend upon agriculture for their food as well as their livelihood. They are also responsible, at least in part, for the environmental degradation that has been accelerating in recent years. Research is needed to have a better understanding of the smallholder culture and needs, and to enhance the adoption of systems that emphasize both food production and environmental conservation (CIMMYT 1988). The farm family should be the focal point for these investigations and should, to the degree feasible, actually participate in the research. This bottom-up approach would help researchers gain a better perception of the problems that they are trying to solve and the steps needed to solve them. They would also change the agricultural research agenda to a demand-driven mode, and would involve the farm families in its planning and implementation.

The socioeconomic policy framework that creates incentives for farmers and generates demand for viable agricultural technologies and services, would eventually lead to a robust growth in farm production and incomes. Following reforms and policy structures are proposed :

- Enhance demand for traditional and novel food products, thus creating demand for farm produce and higher prices for farmers.
- A farmer friendly trade and price policy, both for farm produce and " inputs" so that agriculture would not be subject to " net taxation" in real terms.
- Greater security of land tenure to encourage investment in land conservation, in particular a review of communal land tenures and common property rights.
- Provision of a better rural infrastructure, including roads to reduce the cost of input supply and marketing, processing and marketing facilities to help the farmer reap a larger part of consumer price, and improved financial services, to help farmers to save as well as borrow for investment.

CONCLUSIONS

It is apparent that the challenges of food security are intimately related to those of environment and ecological security. Our present predicament would demand a continuing increase in productivity and total output ensuring food production levels to accommodate the increasing population and maintaining the quality of the resource base. It is also clear that crop production based on chemical fertilizers and pesticides will not be able to produce the needed results. The new paradigm must enable us to develop strategies for improving production that takes into account the potentialities and limitations of natural resources, climate, soils, water, and vegetation for their sustainable use. Biodiversity-based (both soil and above ground diversity that integrate crops, livestock and trees) crop production system that harnesses good agricultural practices seems an emerging paradigm that potentially addresses issues of environmental degradation associated with agriculture while enhancing crop production. For some, this may still be debatable, but for those who have had a feel of this paradigm through thousands of practising farmers harvesting high yields in at least six developing countries, this may be the way forward (Thrupp 1996, Pretty 1998) to feed the world.

Traditional crop improvement research backstopped by modern biotechnology must create crop varieties that will tolerate or overcome the adverse effects of pests and diseases, drought, soil toxicities and climatic extremes. These varieties must fit into farming systems that minimize natural resource degradation and enhance the economic well being of the farmers. Robust indicators of sustainability are required that recognize the interdependence of economic and environmental sustainability and the potential trade-offs between them.

For sustainable crop production to succeed, decision makers need to commit themselves to long-term financial support of agricultural research. At the same time, researchers must sharply focus their efforts on high priority areas that will provide the best for most of the people.

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