

Sustainable Agriculture: Critical Challenges Facing the Structure and Function of Agricultural Research and Education in India¹

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Abstract

India's National Agricultural Policy accords high priority to the sustainability of agriculture. ICAR and the State Agricultural Universities, which comprise the National Agricultural Research System (NARS), also emphasize the importance of incorporating the sustainability perspective into their research and education programmes. But this requires an analytical framework for sustainable agriculture that can guide a transition from research and education directed towards productivity goals to research and education that addresses productivity issues keeping sustainability concerns in sight.

This paper proposes such a framework based on an identification of agricultural production systems at different levels and their linkages, assessments of production requirements and supplies over time, tradeoffs between production increases and the quality of the natural resource base, and the capabilities of knowledge and technologies to alter the balance of tradeoffs. The paper also identifies the challenges posed to the existing agricultural research and education systems in India in the transition towards sustainable agriculture.

Introduction

The National Agricultural Policy (Ministry of Agriculture, 2000) of the Government of India aims at agricultural growth (4% annually to 2020) with sustainability, by a path that will be determined by three important factors: technologies, globalization, and markets. Agricultural research and education of the future must therefore address two related challenges: increasing agricultural productivity and profitability to keep pace with demand, and ensuring long-term sustainability of production.

The National Agricultural Research System (NARS) deals with the first challenge. Development of short-duration, high-yielding cultivars, irrigation, and intensive use of fertilizers and other agro-chemicals provided the technological basis for increasing agricultural production and the green revolution. Central to the adoption of green revolution technologies were the micro or farm economics - which governed the use of inputs such as land, cultivar, labour, machinery, and chemicals balanced against profits from crop yields - and the macro economics that ensured better access to inputs and markets. The research and education systems have evolved within this framework with a commodity/ productivity focus.

Sustainability as a goal of agricultural research and development is a relatively recent concept. In recent years, national and international research organizations have responded to the increasing importance of sustainability in agricultural development. The Indian Council

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of Agricultural Research (ICAR) has also revised its mandate; its new vision statement reads, "to harness science to ensure sustained physical, economic, and ecological access to food and livelihood security to all through generation, assessment, refinement, and adoption of appropriate technologies," (ICAR, 1999). Nearly all institutions of ICAR and State Agricultural Universities (SAUs), which constitute the NARS, have new vision statements focusing on "productivity with sustainability."

But integrating the concept of sustainability into the institutional strategy and design of research and education programmes is proving difficult because sustainability requires dealing with interactions between technology, society, and environment and therefore with multiple stakeholders. It broadens the both scope and scale of agriculture from farm production and profitability to agribusiness issues that encompass regional and global development and environmental concerns. To address such concerns, a transparent and integrative analytical framework is needed (National Research Council, 1999) through which the stakeholders can understand the interactions and discuss, define, structure, formulate, and measure concepts, issues, and criteria related to agricultural sustainability and its assessment. This process is necessary for the effective redesign of agricultural research and education systems for sustainability. This paper presents such a framework.

Development of Analytical Framework for Sustainability

Central to the analytical framework is a set of acceptable *definitions, objectives, indicators and their criteria, and technologies* which can contribute to the practice of sustainable agriculture while maintaining the focus on increasing agricultural productivity and profitability.

Definitions: Any definition of sustainability must recognize its multiple dimensions: physical, economic, ecological, social, cultural and ethical. Sustainability can be defined only in the boundaries of a system's framework, that is, after specification of what is to be sustained. Choosing the boundary is difficult because agricultural systems operate at multiple levels: soil-plant system, cropping system or farming system, agro-ecosystem and so on to higher regional, national, and global levels (Lynam, 1994). The level chosen thus also defines the spatial scale of operation for the definition. Decisions at the farm level have impacts at the agro-ecosystem and higher levels and *vice versa*. The linkages between agricultural systems at different levels of hierarchy (spatial scales) are important.

The US Congress arrived at an acceptable definition for sustainable agriculture (Stuart and Robinson, 1997) for the USDA and its Agricultural Research Service (ARS) after considerable national debate. The definition broadly allows addressing issues for systems at different levels and the linkages between the systems up to the agro-ecosystem level. By this definition, an agricultural production system is sustainable if, over the long term, it enhances or maintains the productivity and profitability of farming in the region, conserves or enhances the integrity and diversity of both the agricultural production system and the surrounding natural ecosystem, and also enhances health, safety, and aesthetic satisfaction of both consumers and producers.

Reduced use of synthetic chemical inputs, biological pest control, use of organic manures, soil and water conservation practices, crop rotations, biological nitrogen fixation, etc., are all relevant and important technological components of sustainable agriculture. But central to the concept of sustainability is the integration of these components in a systems

framework at specified levels and to meet specified objectives. The above definition may be considered an acceptable starting point for the Indian NARS as well.

Objectives: It is important to clarify the sustainability objectives: What is to be sustained, for how long, and at what level? These questions have to do with national or regional policies and goals for agricultural production. For example, in view of India's large population and for strategic reasons, food production goals have been synonymous with food self-sufficiency. On the other hand, China, which also with a large population, has recently been forced to giving up the goal of self sufficiency in food grains because of severe water shortages (Brown, 2001). Thus sustainability objectives will be governed by national or regional policies for agriculture in particular, the economy in general, and by the supply capacity of natural resource base.

Indicators and Criteria: Sustainability indicators are quantifiable and measurable variables that can be used to evaluate system performance with relation to its objectives. Since sustainability concerns system behaviour over time, a sustainable system is one with a non-negative trend in these variables. Technology adds to sustainability if it adds to the slope of the trend line. Because of its multidimensionality, a suite of indicators will be required to make realistic assessments about sustainability. TABLE 1 provides an indicative list of such indicators.

Technologies: The recent revolutions in biotechnology and genetics, and in information and communication technologies, radically change the conceptual framework of managing agricultural production systems. Another dimension is added by the recent realization of the gains that can be obtained by the inclusion of ancient wisdom and knowledge acquired by generations of local farmers in sustainable management of resources. These developments, when complemented with knowledge from conventional agricultural research, hold the key to ensuring both sustainability and productivity increases in agricultural production.

Table 1: Sustainability indicators (adopted from RIRDC , 1997)

Hierarchical level	Sustainability Indicators (economic, social & environmental)
Cropping system/ farming system	Non-negative trends in: <ul style="list-style-type: none"> (i) farm productivity (ii) net farm income (iii) total factor productivity, (iv) nutrient balance (v) soil quality (vi) residues in soil plant products (vii) farm water use efficiency (viii) farmer skills/education (ix) debt-service ratio (x) health (xi) time spent in other social cultural activities
Agroecosystem (watershed, Agroecozone, etc)	Non-negative trends in: <ul style="list-style-type: none"> (i) regional production (ii) regional income (iii) regional total factor productivity (iv) regional nutrient balance (v) income distribution (vi) species diversity (vii) soil loss (viii) surface water quality (ix) groundwater quality (x) regional social and economic development indicators
Global,National,Regional Systems	Indefinitely meet demands at acceptable social, economic, and environmental costs.

The new biotechnologies do not hold the same promise of providing quantum jumps in crop yields as the green revolution technologies did. The World Bank estimates that biotechnologies can help increase crop yields in rice by 10- 20 percent in the next 10 years (Serageldin, 1999). But they have the potential for speeding up the research (for example biotechnology permits faster transfer of genes), and doing "maintenance research" which is research that helps prevent losses in yield and allows crop to use fewer inputs. Examples are the incorporation of genes for pest resistance, improved storage and packaging, fixing nitrogen from soil, etc. Similarly improved resource management through the use of information technologies permits more efficient use of inputs for the same level of crop yields, thus reduces the deterioration of natural resource quality. Whereas the green revolution technologies led to quantum jumps in crop yields, the new biotechnologies and

information technologies, as well as the indigenous technologies and knowledge, are tools for achieving incremental advances in yields and maintaining the yields in a sustainable fashion.

The Framework: The framework of sustainable agriculture is determined by:

1. The food demand of the growing population and economy (sustainability goals), and the supply limits set by carrying capacities of the agroecosystem (system capacities),
2. The tradeoffs between agricultural productivity and quality of the natural resource base in different regions/agroecosystems as assessed by trends in suitable sustainability indicators, (Are the levels and growth of production sustainable?), and
3. Emerging technologies and improved management strategies that can shift the tradeoffs towards improving both sustainability and productivity. (Can prospects for long term sustainability be improved with new technologies and management?)

The framework is to be applied at two levels considered relevant to the NARS : the crop production system level and the agroecosystem level. Keep in mind that for agriculture to be sustainable, it must be profitable in the short term. Thus two time perspectives-- the short term and long term--are also needed. The sustainability indicators of profitability and social concerns based on income generation and distribution are effective in the short term compared to the ecosystem health indicators, which require a longer time to take effect. The analytical framework is complete when the systems at different hierarchical levels are linked (FIGURE 1) in a scheme that permits the three questions above to be asked and answered at each level.

Implications for Research

The above framework helps define a vision for agricultural research, target it effectively to prioritize investments and set production and productivity goals at various levels that match national goals. But, it calls for a major paradigm shift in agricultural research and education from the current commodity and input- based approach to management of agricultural resources, to an approach that emphasizes a systems framework and process-knowledge-based management to increase production. The new emphasis is on alternatives to agrochemical use and increasing the rates of existing biological processes to control nutrient cycling and pests. The concept of economic discounting of future value of natural resources is also altered. All of these will place far greater demands on research capacity and farmer knowledge (Lynam and Herdt, 1989). They will also require agricultural research to become more grounded in theory than it has been so far. Other major issues for agricultural research policy and design are described below.

- ◆ **Characterization of Systems:** Research designs for sustainability will require clear characterization of production systems, agroecosystems and their boundaries, the marketing systems, and the linkages between them.

Setting objectives: An appropriate balance is required between commodity focused research based on intensive use of agrochemicals (which formed the research paradigm up to now and which was responsible for the green revolution) and the resource management focused research (which forms the backbone of research within the sustainability paradigm)..

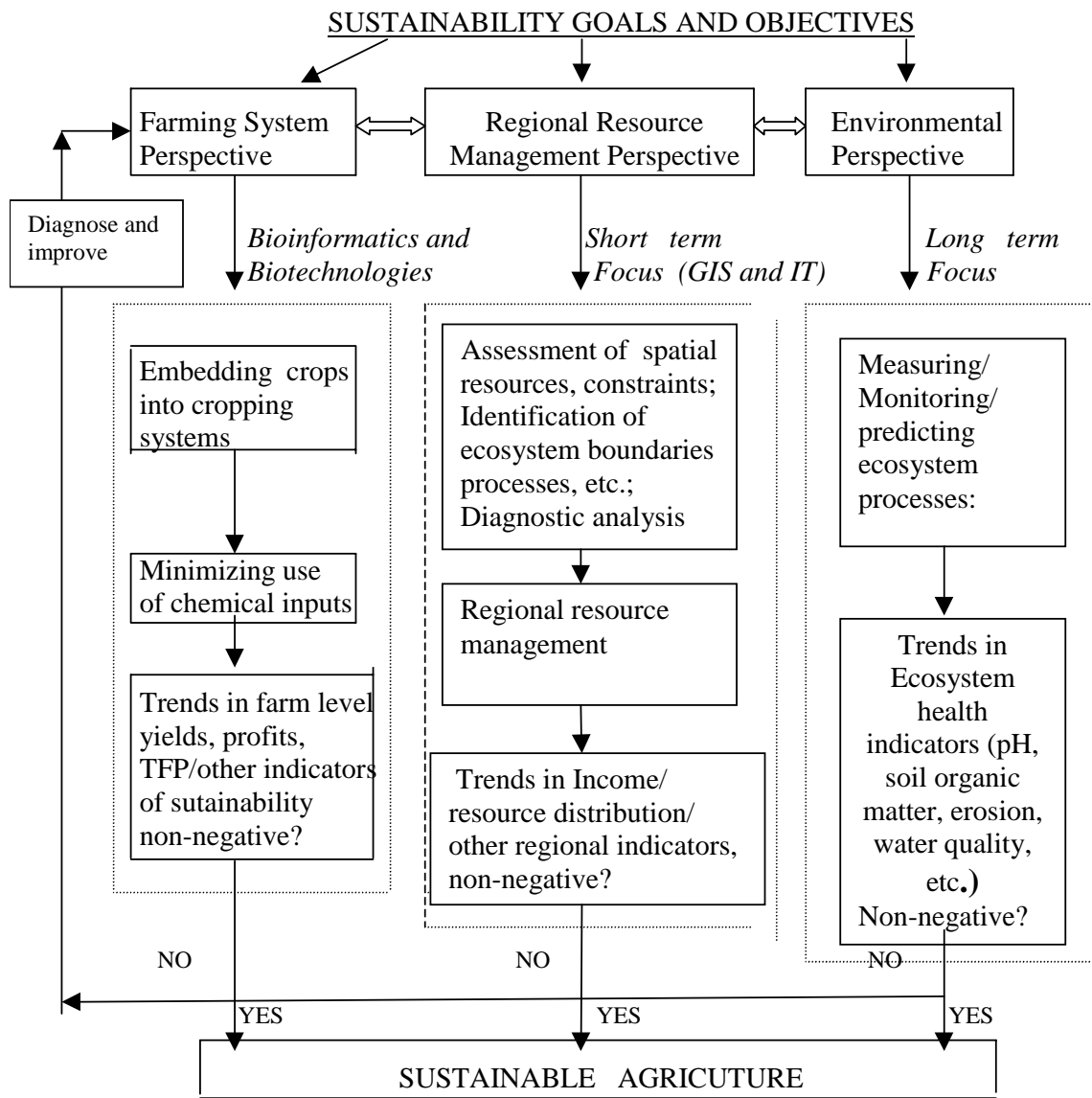


Fig.1: Analytical framework for sustainable agriculture (adopted from Barnett et al, 1995)

- ◆ **Research prioritization:** Higher priority would be needed for research on systems which currently are tending towards unsustainability. and to problems which are contributing most to the degradation of the system.
- ◆ **Externalities and measurement of sustainability:** Research will have to be initiated on identification and measurement of externalities and tradeoffs to develop sustainability

indicators for agricultural systems at different levels. This research will be interdisciplinary and will need interactions with economics and ecology, and between theory and experiment.

- ◆ **Farmer response:** The demands on farmer knowledge and responses will be much higher for sustainable agriculture than for traditional agriculture.
- ◆ **The organizational challenge:** Incorporating the sustainability perspective into research policy, design, and management will require important organizational changes in the Indian NARS. Major changes in all the three vital organizational components, namely, its structure, systems, and skills will be required.

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1. Many of the impacts of research with a sustainability perspective are measurable not at the farmer's field level but at the higher regional level. For the technologies to take effect at this level, they must be deployed sufficiently widely by a large number of farmers. Thus new technologies resulting from research must be brought to scale before they can deliver the objectives at the regional level.
 2. The sustainability perspective requires frequent interactions and feedback between simulation modeling (improving process knowledge) and empirical field experiments. New multidisciplinary research teams, designs and skills will need to be developed to ensure effective interaction between modeling and field research.
 3. Unlike commodity research, whose main clients are individual farmers, the new research counts among its clients: farmers, groups of farmers, and policy makers. Organizational linkages will need to be built for interaction between the stakeholders at all these levels.

Implications for Agricultural Education

Integration of research and education is central to the creation of SAUs in India. The challenges faced by the agricultural research system in incorporating the sustainability perspective will also be applicable to agricultural universities in general. In addition, SAUs face the additional challenge of incorporating the sustainability perspective into their education programmes. These programmes have evolved around the prevailing green revolution paradigm of high-yielding varieties, input-intensive management and relative certainty in defining the production systems. The typical organization of any SAU points to their basis being in this paradigm: they are organized into disciplinary divisions and focus on the major economic crops in the area of their operation

The empirical base of agricultural education served the green revolution era well. But, the strengths of the system for that era may well turn out to be weaknesses if the sustainability is to be designed in to agricultural systems. The sustainability paradigm requires a transition to process- knowledge -based agricultural education with emphasis on problem identification and solving skills. For example, the conventional education in agricultural statistics and experimental design (which forms the very foundation of agricultural education and research) needs to be entirely overhauled, if sustainability becomes the goal. Rather than looking for a single solution that will serve in all locations, sustainable agriculture demands site- specific precision agriculture that allows different solutions under different conditions. In general, good training in basic sciences provides problem-solving

skills that can instill confidence and better handling of practical situations. In the past, the SAUs have not placed much emphasis on basic science skills and will have to build their strengths in this area.

In addition to the changes required in the knowledge base of agricultural education, sustainability requires serious didactical reorientation (Wals, 2000). The defining metaphor of education should change from tending a garden to leading an expedition. The traditional view, also reinforced by the objectives of the Model Act for Agricultural Universities, is that a university produces graduates with a set of skills that can be used in the marketplace. The teacher is like a gardener who tends to the flowers (students); s/he prunes and shapes them into marketable products. In a commodity/productivity based agriculture, with relatively stable markets, the gardener metaphor was a valid one. But in the sustainability perspective, the teacher and student are both explorers. The skill sets required are a solid grounding in basic science and disciplinary skills, communication and information management skills, and self learning skills that provide the capabilities to understand and adapt to change. The teacher is the leader of an expedition and a partner in the learning process focusing on building the self-learning and problem-solving abilities of students. The inherent difficulties in identifying relevant systems and defining and measuring their sustainability only reinforce the need to move to a metaphor in which teachers consider themselves to be learners as well. Significant changes in attitude of both teachers and learners will be required.

Developing capacity for self learning will require access to self learning facilities (both for students and faculty) to enable people to learn to understand and adopt to change. These facilities include well-equipped libraries and laboratories and access to worldwide learning resources through information technologies. Specific training and formal evaluations in self-learning are required. Thus the challenges facing agricultural education range from conceptual and thematic to institutional and individual. Major changes will be required in the structure, systems, and skills of NARS before the sustainability perspective can be effectively incorporated into agricultural research and education.

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