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The Twenty-First Dr R.V. Tamhane Memorial Lecture*

UNCED Agenda 21: The New Challenges for Soils Research

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I am honored to be invited by our Society to present the 1994 Dr R.V. Tamhane Memorial Lecture. The entire concept of soils research has reached a cross-road. In many university systems and research institutes all over the world, the departments of soil science are being merged with the newly created divisions of natural resources - of which soil is one (Miller 1991; Yaalon 1993; Warkentin 1994; Wilding 1994 a). In some institutions, soil science is considered as a component of environmental sciences. I believe it is a good time to review in general, the path that soils research has taken, and then consider the direction it must take in the years to come so that soil scientists continue to contribute to the welfare of our people, keeping in perspective several agenda and resolutions made at the 1992 United Nations Conference on Environment and Development. Its Agenda 21 adopted at Rio de Janeiro concerns agriculture (Keating 1993). It is increasingly referred to as UNCED's Agenda 21. To operationalize this Agenda, I believe the scientific contributions of Dr Tamhane could be a useful guide for us to chart our future.

Modern soil science is about 150 years old. Over these years soil researchers have generated a wealth of information on the nature, properties and management of soils under diverse agroclimatic conditions. Applications of the knowledge of soil science together with those of genetic, agronomic, engineering and social sciences have kept Malthusian predictions at bay, at least for the present in the Asian continent. The world grain production has continued its upward trend, while the area harvested has declined. Despite the declining trend in grain area harvested, worldwide per capita grain production has been maintained at about 325 kg since 1975 (Brown *et al.* 1993).

The New Setting

We are poised at the most remarkable transitional point in the history of agriculture in the final decades of the 20th century. Before the beginning of this century almost all the increases in agricultural production occurred as a result of expansion in the cultivated area. In India this process occurred almost until 1965; when science-based agriculture intervened in what is now popularly termed as the Green Revolution.

The big gains of scientific agriculture resulted from the introduction of high yielding varieties of wheat, rice and other crops, primarily in secured irrigated environments. Indeed during the past 30 years, Indian agriculture has undergone a revolution more profound than any other development in the past. The use of chemicals has increased several fold. Farmers have begun to take advantage of these opportunities and have improved their productivity. Increased specialization in agriculture is apparent in about a third of the total cultivated area of the country. Agricultural research has been seen as good investment both by the public and the private sector.

Land Resource Limitations

The population pressure on the resource-limited world is already heavy. It has been projected that the global population would double over the next 40-50 years and stabilize around 10-12 billion.

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The ratio of land to people will reduce to 0.15 ha per person from the present 0.3 ha per person by the year 2050. For India, land use figures are most revealing. Dr S.B. Kadrekar who gave the 20th Dr R.V. Tamhane Memorial Lecture last year (Kadrekar 1993) stated that our land:man ratio is now approximately 0.14 ha per person, and when India's population stabilizes at around 1.5 billion by the middle of the next century the per capita availability of land may reduce to anywhere between 0.09 to 0.05 ha per person. Only 500 m^2 of cultivated land or less per person would be available to feed the burgeoning population. Even if we maintain the present level of food intake, in another 40-50 years we would have to produce on average 4000 kg of food on each cultivated hectare of land. Contrast it with about 1500 kg ha^{-1} of food production today. The gap is remarkable. We have a long way to go.

Land Sparing Technologies

Nobel Laureate Norman E. Borlaug advanced the concept of land sparing technologies in his keynote address to the 15th World Congress of Soil Science held at Acapulco, Mexico in July 1994. In this he compared the recent agricultural production trends of USA, India, and China. According to him, USA in 1940, produced a total of 252 million tonnes (Mt) of food and fibre from 129 Mha of land. In comparison in 1990, American farmers harvested 600 Mt from 119 Mha of land - some 2.5 times more production from some 10 Mha less land. He argues that if the United States had attempted to produce 600 Mt of food and fiber with the 1940 technology, it would have required an additional 188 Mha of land. This theoretically would have meant bringing under cultivation a large proportion of forest, or pasture or range-lands.

Borlaug further compares the impressive saving in land use that have accrued to China and India through the application of modern technology. He argues that if cereal productivity of 1961 had prevailed in 1992, China would have needed to increase its cultivated cereal area by more than 3-fold and India by about 2-fold to equal their 1992 harvests. Such a large tract of agricultural land is obviously not available (Borlaug & Dowswell 1994).

Thus due to agricultural advances and the progressive adoption of improved technologies during the past three decades the gains in food production have exceeded the population growth. However, the race continues. We will have to increase production until the population stabilizes, *i.e.*, when we achieve a zero population growth. Unfortunately in many parts of the world and in this country, most of new population increases will occur in areas where a web of inter-related reinforcing factors maintains rural poverty, unplanned population growth, expansion of farming into marginal lands, deforestation, soil erosion, water pollution, degradation of land and unsustainable agriculture (IBSRAM 1994). The UNCED Agenda 21 calls for urgent action on these land and environmental issues. It proposes that agricultural development in the future must be sensitive to social needs but at the same time be fully aware of environmental issues. Thus the slogan for India should be: *produce and protect.*

Sustainability Issues

Despite significant growth of agriculture, the failures of several new farming systems based on high input agriculture are evident. These systems are showing signs of fatigue. In many of the current land use systems, for example the cotton-based cropping systems, or the rice-wheat rotation system in the Indo-Gangetic plains of Pakistan, India, Nepal and Bangladesh, the crop yields have either plateaued or are showing a declining trend in some ecoregions. The hazards of chemical residues have increased. These agricultural production systems, in the past, have focused only on intensifying crop yields while ignoring the wider general implications of changes in agricultural practices on the state of natural resources. Environmental concerns including loss of biodiversity and land degradation, damage to water quality, storage and distribution facilities, and other offsite damages have not been given sufficient prominence. A new impetus must be given to soil related studies, on an holistic basis, and on a large spatial scale, *e.g.*, a hydrologic, a catchment, or a watershed unit. In addition, many studies have shown that land degradation issues, to be considered properly, have to be studied over a long period of time (Oldeman *et al.* 1990). These manifest over time scales of one to several decades in most agricultural soils. Such studies are therefore expensive both in terms of interdisciplinary man-power needs; scientific data collection, assembly and maintenance needs, and for a continued allocation of resources (Eswaran 1994). We should review the present status of many of the 'long term' studies for their usefulness and modify them as necessary to respond to the issues underscored by Agenda 21.

The sustainability of less endowed areas or stressed ecosystems presents enormous scientific, technical, management, and resource allocation problems. Such areas may be defined as those that have either severe soil related constraints to crop production; or are too dry or too wet; or present problems of accelerating environmental damage. Our current system of prioritizing research is mainly based on the number of hectares of a commodity grown in a given area and its importance in terms of monetary output to the national exchequer. Additional factors such as the potential for soil degradation, risks to inter-generational equity, poverty and gender issues are generally ignored. Therefore the more endowed environments get all the attention of the political systems. In India, the irrigated areas may be classified as 'well endowed' regions. The stressed environments are more or less ignored. ICRISAT in its Medium Term Plan for the 5 year period 1994-98 has made a beginning in integrating several inter-dependent factors related to sustainable agriculture in its research portfolio priority setting for rainfed areas (ICRISAT 1992; Ryan 1994). This example is worth emulating. However, it was noted that available databases on soils and environment are far from adequate. These are not available in a consolidated format. Relatively few results of well conceived and well run experiments were available. We need, according to Hari Eswaran, a set of multidisciplinary projects of integrated studies at well selected benchmark locations that will lead to recommendations for sustainable land use in a range of agro-environmental settings, based on social, economic, and equity considerations (Eswaran 1994).

The New Agenda

In order to recommend new technologies for sustainable development that are sensitive to Agenda 21, we the scientists interested in the maintenance of the continued production potential of the soils must give greater and more focussed attention to some of the following issues:

1. First, we should be able to anticipate soil, water, and nutrient related problems and other land related factors that unsustain production systems (see for example IIASA 1994). In order to do this we will have to develop methodologies and protocols to delineate production domains, and prescribe action options for correcting factors that do not encourage sustainability of food production or those that aid natural resource degradation. The basic spatial unit for such research should be a well defined and well quantified agroecological zone.

2. Second, we should, as soil scientists, develop expertise in the delivery of tool-kits which aid in introducing productive, economically safe sustainable food production to land managers (farmers) and decision makers. These should result in improvement of natural resource use across production domains over a range of agroecologies.

3. Third, we must intensify soil management research on issues identified by United Nations Conference on Environment and Development in its Agenda 21. In order to make myself clear, let me cite a few examples in some detail:

   * Chapter 9 of Agenda 21 refers to protecting the atmosphere by regulating fluxes of CO_2, CH_4 and N_2O from the soil. Our new soils research must target methods of increasing sinks so that emissions of environment damaging gases are reduced.

   * Chapter 10 of Agenda 21 refers to the management of land sustainability. This chapter

has great significance for our current and future soils research. Soil management concerns such as physical, chemical and biological degradation are highlighted in this chapter. My search for evidence, from the pages of the Journal of the Indian Society of Soil Science over the past 5 years, of integrated studies in which both the crop production option and the land management option have been evaluated in 'tandem' was not very successful. A great number of soil and water conservation studies are reported. Similarly a large volume of research data on studies pertaining to varieties, fertilizers, dates and rates of planting, and water management, are also reported. What is missing very clearly are studies on their integration and interaction.

You are well aware that soil erosion is a major cause of soil degradation in tropical environments. Many methods of soil and water conservation have been advanced by the research institutions that reduce soil loss under experimental conditions, or under scientist-managed on-farm conditions. However, large-scale adoption of such techniques, at farm level, is not evident (Abrol *et al.* 1994). Soil erosion is one of the main causes of lack of sustainability in agriculture. In order to fill the call given by Chapter 10 of Agenda 21, interdisciplinary studies should be planned by land use scientists, land and water management specialists, and soil conservationists so that integrative farming systems technologies are developed that complement soil conservation aspects with increased productivity. Here again, let us consider an example, which emphasizes the issue. In the Vertisol region of Central India, vast tracts of land are left cultivated-fallow during the rainy season. Crops are grown in the post-rainy season on conserved soil moisture. There is a considerable amount of soil erosion. The soil loss may range between 5 and 100 t ha^{-1}. In the farm surveys conducted by CRIDA and ICRISAT, it was found that seed-bed preparation and planting of crops after the onset of the rainy season was difficult because the soil was too sticky. The technical solution was to cultivate the land ahead of the rainy season, and prepare the seed-bed in advance, so that crops are sown just before the onset of the rains. A multidisciplinary of team of agroclimatologists, soil physicists, land and water engineers, economists, and agronomists found that it is possible to define in a probabilistic sense, the periods during the year when the land would be in a condition when rough-cultivation is possible; the planting time could also be defined for dry sowing of crops by using long-term weather data; and the agronomists and engineers worked out appropriate planting techniques. The economists and engineers worked out appropriate planting techniques. The economists identified the most productive cropping options. At the ICRISAT Asia Center during the past 16 years, the rainy season crop have been established by this method. Dramatic productivity increases have been shown. At the same time the soil erosion loss have been checked to a large extent (Srivastava & Jangawad 1988; Virmani & Eswaran 1989). We need to multiply such examples. In the improved Vertisol management technology, the maintenance of green vegetative cover throughout the rainy season has been used to control soil erosion in association with mechanical or engineering methods. I know some similar techniques have been suggested by the Central Soil and Water Research and Training Institute and the Universtiy of Agricultural Sciences at Bangalore that need to be popularized.

* Chapters 11, 12, and 13 of the UNCED's Agenda 21 refer to deforestation, desertification, drought, and sustainable mountain development. Alternative systems of land use that incorporate elements of agroforestry need revisitation. The whole area of combatting droughts and desertification needs to be undergrided by social science and climatic research. The management of steeplands in

mountain areas calls for a development strategy which is socially acceptable but is low cost, productive and results in conservation of natural resources.

The final chapter of direct relevance to soil scientists is the Chapter 14, which deals with sustainable agricultural development. As I interpret it, it suggests in no uncertain terms, that in case the soil scientists wish to continue to receive the attention of the policy makers, they must make available technical options for sustaining agriculture which could be tied-to and inter-linked with sustainable development. In case we continue to 'plough our lone-furrows' we would be side-tracked and by-passed. Dennis R. Keeney in his presidential address given at the 1993 annual meeting of the American Society of Agronomy gave a call to the world farm scientists to "Building Bridges" with other sciences so that integrated technologies are evolved (Keeney 1994). On a similar theme, Larry P. Wilding, gave a call to soil scientists that they must "Enlarge the paradigm of soil science" (Wilding 1994b). He said we have two choices: "we may either be proactive and lead the parade of earth sciences or status quo and complain about being on the side lines. An enhanced program, beyond the traditional agriculture role is needed to expand the vision of soil science or we will likely be in the latter camp". The opportunities for soil scientists are almost unlimited; what is limiting us is our vision of the future.

The Mission for the 21st Century

In the closing decade of the 20th century, let us devote some thoughts on the soil science research agenda for the 21st Century. The opportunities to continue probing subjects of national and international importance are many. There are needs for a new and bold initiative. Let me offer a few suggestions for your consideration.

1. The time for the large scale extension of high-input packages which have resulted in dramatic increases in food production in the tropics is over. In the future, according to Pedro Sanchez, we would have to "rely more on biological processes by adapting germplasm to adverse soil conditions, by enhancing biological activity and by optimizing nutrient cycling to minimize external inputs and to maximize the efficiency of their use (Sanchez 1994);
2. Having defined for ourselves a set of challenges as contained in UNCED's Agenda 21, which calls for a sustainable approach to the management of the natural resources across eco-environments, we must see soils research as a part of a large body of research on environmental sciences in a continuum (Miller 1993);
3. The recent Cairo Conference has reminded us of the continuing need to increase agricultural production while safe-guarding the natural resource base. In a country such as India, the two needs must most acutely meet. The issues related to food security and to the rapid depletion in the quality of natural resource base are a matter of growing concern. Considerable part of our future research portfolio must be devoted to issues related to sustained productivity and environmental protection;
4. Strategic use of input is an area of challenge to soil science. Use of integrated nutrient and water management systems for increased efficiency of inputs continues to remain weak. A vastly improved database on the geographical distribution of soils, their classification according to quantitative criteria and their interpretation for soil related constraints are now available. Its use in client-friendly terms needs to be enlarged. The work done by the Soil Survey and Land Use Organizations of India has been examplary. Some credit for this achievement must go to Dr R.V. Tamhane who in his early career as a soil survey officer and later as an advisor on soil conservation to the Government of India, initiated many programs that have led to a precise definition of edaphic constraints. We must set up mechanisms for the global assessment and monitoring of soil resources and use them as a part of decision making matrix;

5. An area of research which continues to remain underdeveloped, is our capacity to forecast the seriousness of the soil degradation. A set of early warning indicators need to be developed for different agroecologies. We should be able to relate the soil degradation to loss in productivity and suggest methods of amelioration; and finally,

6. Soil scientists should assist in the development of methods to assess agroecological potentials for different land use systems. They should provide data on yield gaps that currently exist, and the technical steps that need to be taken to close the yield gap so that sustainable agricultural technologies are introduced to optimize crop yield (Buol 1990). It should be ensured that improved technologies upgrade the natural resource base over time.

Harmonizing Soil Science Activities in Times of Change

Times have changed. Research agenda have changed. Perceptions have changed. And therefore, in order to be relevant and impact oriented, the activities conducted under the banner of soil science must also change. Our pursuits must match the needs of the 21st century. Let me make a few suggestions that must the considered as initial thoughts from someone who is interested in accelerating the progress of soil science to meet future food and environmental demands. I am fully conscious that there are several institutions involved in such activity. I would limit my comments to the three obvious ones: the Indian Society of Soil Science, the national grid of research institutions in the public sector, and the state agricultural universities. Let me elaborate:

□ *The Indian Society of Soil Science:* Our Society has had a glorious past. During the 60 years of its existence, the Society has nurtured the general subject of soil science and agricultural chemistry extremely well. It has had some of the best soil scientists at the helm of its affairs. In the coming decades through its various fora it should

* *facilitate* communication of scientific and technical information on sustainable management of natural resources including soil resources;

* *commission* reviews to identify priority issues related to improved land management for use by a comity of sciences and decision makers at all levels;

* *encourage* problem-based research on high priority issues and proactively propose an international seminar/workshop in association with other institutions;

* *assist* research and educational organizations across the country in restructuring their soil science related research portfolios so that the effectiveness of their efforts is increased; and finally,

* *enhance* awareness of the central role of soil research in addressing issues related to sustainable development. The society may undertake public literacy in earth sciences, take interest in legislations dealing with land affairs, help changing public perceptions on urban and rural land use and impacts of waste management on the quality of life.

□ *The National Research and Development System:* It is now time that a major restructuring of the national agricultural research systems dealing with natural resources and sustainability of agriculture is vigorously pursued. In a talk given recently by Abrol (1994) on the topic "Our Changing Research Agenda" at the Andhra Pradesh Agricultural University, he lamented that much of our agronomic research aimed at developing management practices is repetitive. I suggest therefore a consortium research approach could be adopted in place of disciplinary or commodity projects that are currently in place. The consortia must have a defined time frame of existence - patterned somewhat after the technology mission based approach that the Government of India had launched some years ago.

Let me discuss an example to explain my view-point. I have given a reference to rice-wheat rotation in my earlier remarks. It is a popular cropping system among farmers in the Indo-Gangetic plains. As I noted this rotation is now showing signs of stress. The yields of the component crops have not shown significant increase during the past few years. A consortium to characterize symptoms of its unsustainability, biophysical problems, delineation of stressed ecozones for different types of constraints, and definition of areas where the rotation can be successfully implemented may be initiated. Such a consortia approach would allow for linkages with the international and state research/development systems. The consultative Group on International Agricultural Research in cooperation with CIMMYT, IRRI, and ICRISAT has already proposed a rice-wheat consortium. The objective of this initiative is to link the national research and development agencies with international institutions so that emphasis on a research paradigm to sustain productivity of this important cropping rotation is continued. You will appreciate that for us in India, the results of this research have a strong bearing on the food security of the country.

A number of other such consortia can be thought of. Some of the subjects worthy of consideration are: improving soil, water and nutrient management; sustaining ecological balance of deserts, expanding agroforestry in crop lands, managing productivity of acid soils, controlling degradation of sea-land margins, *etc.*

Agricultural University Systems: India is one of the few developing countries where strong foundations for an inter-linked system of agricultural research, education and extension exist. The departments of soil science are embedded in the colleges of agriculture. In order to train the soil scientists of the future, institutional reorganization, departmental name changes, curricula revisions, which are currently underway in the United States of America, are needed here. Soil scientists, in order to meet the challenges of the future, must be more holistically trained in agronomic and related earth sciences; in ecological sciences; and in land use aspects of the landscape for sustained natural resource management.

Ladies and gentlemen, it has been a pleasure talking to you on the subject of application of soil science in today's agriculture with a view to sustaining tomorrow's agriculture. The steps that we take today will have a tremendous impact on the sustained productivity of our land and the protection of our environment in the years to come. I trust this is what Dr R.V. Tamhane did in his time. He initiated soil surveys. He put in place schemes for soil conservation. All of these steps must have looked small when considered in isolation. Today those activities have become a corner stone for our national food security. I hope you will join me in remembering the contributions of Dr Tamhane to the broader aspects of agricultural development. We all salute him.

Let me end on a more personal note. While I was driving to the IARI this morning, I was reminded of the happy years that I spent here in the early sixties. I am touched by your invitation. The Indian Agricultural Research Institute is my *alma mater*. It is at its door-steps that I learnt about the intricacies of soil science. The knowledge that I gained here, has stood me through, in many years of my research career, in many countries. IARI is a great institution and we must all endeavor to improve its image and output. Thank you.

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