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Sincerely,

Roger G. Hanson

Roger G. Hanson

RGH:sm

Enclosures

Diamond Jubilee Symposium

Management of Land and Water Resources for Sustainable Agriculture and Environment

INDIAN SOCIETY OF SOIL SCIENCE
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Land Resource Assessment and Monitoring for Sustainable Agriculture: A New Agenda

H. ESWARAN[1], E. VAN DEN BERG, P. REICH, AND P. ZDRULI

Many studies (Davidson 1992; Dent 1990; FAO 1989) point to the endangerment of the finite land resource and question its continued capacity to provide the quality of life that was assured in the past. The increases in population, particularly in those countries that are least equipped to provide for them, the accelerated rate of consumption of natural resources, the degradation of the land resource base with accompanying impacts on biodiversity (genepool depletion) and agricultural productivity, and the impending effects of global climate change, are all converging to emphasize the point for immediate change in the manner that natural resources are exploited (Eswaran 1992). Even if there is a desire to work towards sustainability, the socioeconomic environment in many countries is an obstacle to achieving the desired goals.

It is becoming increasingly evident that managing the land resource base is important to attain the broader goal of sustainability, equity, and environmental soundness (Greenland *et al.* 1994). In some third world country situations, it may even be the key to sustainability and the desired quality of life. A judicious soil, water, and nutrient management policy may be the strategy that triggers economic growth in many countries. This is because managing the environment and assuring biodiversity is a luxury that third world farmers cannot afford and that it can only result from a sustainable agriculture program. Thus, the premise is that sustainable land management (SLM) is a prerequisite to preserving the environment, assuring intergenerational equity, economic growth, and an enhanced quality of life (Dumanski *et al.* 1992). SLM must be in place if all the other desirable qualities are to materialize.

In the last two decades, major changes have taken place in our thinking about research and development for agriculture in general and utilization of the natural resources in particular. Slowly but surely, even in the poorer third world countries, there is an increasing awareness about ecosystem health and maintaining the quality of the environment (Conway & Barbier 1988). In many countries, particularly in the affluent countries, national priorities for environment management are in place while donor countries that provide assistance to the developing world are requiring that this is *sine qua non* for developmental assistance. The rationale being

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that environment transcends national boundaries coupled to the less convincing but valid argument that environment and quality of life are interlinked. The concept of sustainable development initiated by the Bruntlandt Commission (WCED 1987) and amplified by Agenda 21 promulgated by the United Nations Conference for Environment Development (UNCED 1992) have been the driving force behind the new attitudes.

Despite a political commitment to the precepts of Agenda 21 by practically all countries of the world, the implementation of the concept is still elusive in many third world countries. Budgetary constraint is a major impediment but, in addition, there is the daunting aspect of convincing the resource poor farmers of the intricate link between environment and agriculture. Even the scientific community is groping with this new dimension for research and there is no successful program which has grappled with the 'holistic approach' which is now a popular 'buzz-word'. Consequently there is an atmosphere of uncertainty, particularly in the scientific community as to which direction and approach should be taken.

Unilateral decisions by administrators (in the absence of scientific rationale) result when the scientific community is unable to provide strategies and options. Affluent countries have adopted the path of reducing agricultural production with research funding earmarked only for agricultural research having an environmental context. Unfortunately, this view is directly and indirectly (through assistance) imposed on third world countries which still face the challenge of food and fibre production to satisfy the burgeoning population. This message is clearly evident for example in the strategy of the U.S. Agency for International Development (USAID 1994). There is an apparent lack of recognition that democracy building, environment protection, economic growth, population management and health maintenance in third world countries will not materialize until they are sustainable in agriculture and the soil resources are maintained.

The issue in third world countries, as exemplified by the semi- arid tropics of Asia, is summarized by Eswaran *et al.* (1994), "*unsustainable crop yields, unacceptably high rates of soil erosion, deforestation, loss of germplasm diversity, and bewildered farmers who do not know what to do next to eke out a reasonable standard of living still remain the facts of life in the semi-arid tropics of Asia*".

Within this context and that of sustainable land management as a whole, the status and needs for land resource assessment and monitoring is examined. A major consideration is the diminishing budget which excludes many basic research activities. At the same time, recent advances in information technology permit information management and rapid delivery in a more client-friendly manner (IBSNAT 1993). Finally, the demands of this environ-centric world are different from the previous production oriented world, thereby requiring a new agenda for land resource assessment and monitoring (Beinorth *et al.* 1994).

A NEW AGENDA

Despite the fa hat soils form a primary component of the environment, the attention given to soils from the point of view of availability of research and development funds does not match its significance. There is an apparent perception that much is already known about soils and that generalizations made for one site are applicable everywhere. There is also a failure to recognize that agriculture is one of the major 'stressors' of the environment (Virmani *et al.* 1994), particularly from a

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soil degradation point of view. If this attitude prevails, major catastrophies in the near future are more probable.

The purpose of this is not to demonstrate what soil scientists are doing in the area of soils but rather to drive home the point that soil is a 'NON-RENEWABLE RESOURCE' and that society has an obligation to protect it and conserve or even enhance its quality for future generations. This is our basic philosophy. We have to demonstrate the role of society in sustaining agriculture and conversely, the role of soil in sustaining society. We have to evaluate paradigms that brought some countries of the world to agricultural affluence as well as the policies and practices that have contributed to land degradation and decline in productivity in many countries. From here we need to look at current concerns and the urgent need to develop a new paradigm, such as that proposed by Sanchez (1994), that will carry us through the next few decades. We have to demonstrate clearly why some of the valid arguments of the past have little validity in the modern age of environmental degradation. We have to illustrate new concepts and define the research gaps and needs that will enable our institutions to meet the customer requirements of 2020.

Land degradation results from mismanagement of land and thus deals with two interlocking, complex system: the natural ecosystem and the human social system. Interactions between the two systems determine the success or failure of resource management programs. To avert the catastrophy resulting from land degradation that awaits in many parts of the world, the following concepts enunciated by Eswaran and Dumanski (1994) are relevant:

a. environment and agriculture are intrinsically linked and research and development must address both;
b. land degradation is as much a socioeconomic problem as it is a biophysical problem;
c. land degradation and economic growth or lack of it (poverty) are intractably linked; (people living in the lower part of the poverty spiral are in a weak position to provide the stewardship necessary to sustain the resource base. As a consequence they move further down the poverty spiral - a vicious cycle is set in motion);
d. implementation of mitigation research to manage degradation can only succeed if land users have control and commitment to maintain the quality of the resources;
e. agriculture research focus must shift from increasing productivity to enhancing sustainability, recognizing that agriculture can be a non-degradational force;
f. finally, land use must match land quality; thus appropriate national policies should be implemented to ensure this to reduce land degradation; [a framework for sustainable land management (Dumanski *et al.* 1992) is a powerful tool to assess mismatches and assure sustainability].

ELEMENTS OF A NEW AGENDA

The thrust of a new agenda for resource assessment and monitoring has several components, of which four are elaborated below. It must be stressed that any research and development activity need to be in the larger context of the

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ecosystem as discussed later and as addressed by Sanchez (1994) and Greenland *et al.* (1994)

Assessment and Monitoring

Recently there has been discussion of the future of soil surveys and resource assessments. Zinck (1994) mentions some reasons for reduced activities in national soil survey programs: diminishing national budgets, completion of national detailed resource assessment programs in many western countries, changing priorities, inadequate appreciation of the usefulness of soil resource information by decision makers, increasing cost of generating soil resource information, new demands on the quality of soil data, particularly from the modelling community, and the general apathy of developed countries towards agricultural research and the transfer of this attitude to developing countries through technical assistance programs.

Few will question the usefulness of soil resource information. It has been the basis for many advances in agriculture. The surpluses of agricultural products in many of the western countries and some of the developing countries are the result of judicious use of the resource base. Today, the need to preserve fragile lands and enhance and/or maintain production on the better endowed soils is forcing soil scientists to make judgements on soil quality. The role of soil as a filter of chemicals and its niche in the ecosystem also requires scientists to make assessments of ecosystem health. Mitigation technology for containing greenhouse gases requires scientists to evaluate soils from another perspective. All of these rely on detailed or farm-level soil information. Environmental accounting, at the other extremes, now considers soil as a capital investment and is forcing land users to include environmental costs in their production assessment.

Thus, the science of resource assessment is still important but the new users of this information require that it be more quantitative, better georeferenced, user specific, and timely. Information is desired in a user-digestable manner. In the last few decades, several attempts to translate raw resource information in the user-applicable information were attempted. Examples are the Land Evaluation Approach (FAO 1976) and the Fertility Capability Classification (Buol *et al.* 1975; Sanchez *et al.* 1982). With the advent of information technology, there is an attempt through simulation modelling to make land productivity assessment more precise. Geographic Information Systems (GIS) have taken a place of pre-eminence in transfer of technology and information though many GIS users are still only using the tool as electronic pencils and have really not exploited the potentials of the tool.

The new agenda in resource assessment will require the application of all tools of information technology, GIS, Global Positioning System (GPS), databases, simulation models, geostatistics (Stein *et al.* 1988), and new concepts and approaches (Wang *et al.* 1990). Within the next two decades, conventional field soil survey techniques will be phased out due to prohibitive costs and a demand for increased precision of information and will slowly be replaced by tools of information technology and remote sensing. As Dumanski (1994) points out, "*the linking of databases with models at various scales also facilitates analyses of processes and events with a much shorter reference time than is normal for soil survey interpretations*". This will be used as the rationale to seek more cost-effective tools for assessment and monitoring.

The increasing demand for real-time information will require resource assessment to adapt. Monitoring of quality of soil resources will also be subject to the same demands. With the exception of a few examples, monitoring of soil properties and/or processes is not yet a science. It is envisaged that the future will require greater attention to changes of soil properties in addition to kinds of soils. Bouma and van Lanen (1987) have used pedotransfer functions to estimate hydrologic events over a relatively short time frame and such studies lay the basis for the challenges of the next century. A few countries have initiated national resource inventories to monitor the status of the nation's resources. Periodic, every five years or more, assessments provide the basic information for national planning and developing mitigating technologies if large scale detrimental changes are taking place, and for developing research priorities. Suitable indicators of resource quality assist in developing cost-effective assessments, however more studies are needed to develop such indicators for soil resources.

Soil resource assessment and monitoring is entering a new age due to changing needs of users of information, costs, and quality of information. The soil science community must respond to this change. Further, modern classification systems such as Soil Taxonomy (Soil Survey Staff 1994) are challenged by the new demands. National institutions must gear up to meet these new demands and the international community must re-evaluate and develop new concepts, tools and technology to meet these challenges. The 21st century will see a new Soil Science which has little resemblance to the science we know today.

Land Quality and Early Warning Indicators of Land Degradation

The FAO/UNESCO/UNEP 'Global Assessment of Soil Degradation' provides data, albeit subjective, to quantify the current magnitude of the soil degradation problem (Oldeman *et al.* 1992). The United Nations Environment Program (UNEP) and the World Resources Institute (WRI) provide other analyses on these and other aspects of environmental degradation. Although the underlying causes of land/water degradation are socioeconomic, adjustments to these factors will not automatically restore productivity of the biophysical resource base. Thus, soil and water technologies are of critical importance to ensure that production of food, fuel and fibre can be sustained and the environment protected. Efforts to restore productivity of these lands must be coupled with techniques to recognize productive capacity of all soil resources. The ability to flag all stresses, before productivity is significantly impaired (Brinkman 1990), is an immediate challenge. Basis for stressed systems are numerous and include removal of nutrients, development of acidity, salinization, alkalinization, destruction of soil structure, accelerated wind and water erosion and loss of organic matter. In some regions of the world the combination of some or all of these, results in such degradation that the term desertification is popularly used to describe these regions (UNEP 1992). Finally, it must be appreciated that there is an important interaction of the causes of degradation. Erosion, for example, may be flagged as the major problem where chemical degradation of the soil prevents establishment of vegetation and thus leads to an inability of the soil to stabilize against erosion. In this example, lack of appropriate vegetation becomes an early warning indicator. Very few studies have been conducted on this linkage between factors and there is an urgent need to look into this (Lal 1994).

Land resource quality is directly linked to quality of life and specifically social and economic equity, and thus must be addressed in the socioeconomic context for sustainability. In the past, the focus of attention was on rehabilitation of degraded lands. Thrusts in the new Agenda are to evaluate land resources to assess the potential for degradation, manage the resilience characteristics of the systems, and select technological options in the framework of the resilience properties (Eswaran 1993). Consequently, the concepts of 'early warning indicators' and 'land resilience' are relevant (Greenland & Szabolcs 1994). There are few methods to predict onset of degradation and this is crucial to managing systems being stressed. The resilience capacity of systems is also less well established and this must be studied to implement remedial measures to rehabilitate degraded lands. Although soil resource information has been utilized for such purposes, in developing countries either the quality of information or its absence has prevented a more effective use for such purposes (Eswaran 1992).

Land Productivity and Land Use Options

Sustainable land management (SLM) is the key to harmonizing the environmental and ecological concerns of a society faced with the economic realities of producing adequate food and fibre and ensuring a basic minimal quality of life (Dumanski *et al.* 1992, Smyth & Dumanski 1993). SLM is not merely maintaining the integrity of the biophysical land resource base as sustainability can only be realized if land users understand the impacts of land management options so that they can optimize the socioeconomic and environmental benefits of their choice. Insufficient attention is given to this aspect of SLM and consequently, in addition to developing concepts, frameworks, and mechanisms of SLM, a [illegible] effort to link SLM to the socioeconomic realities of the farmer is needed.

A Framework for Sustainable Land Management has the potential to emerge as one of the most powerful tools for the sustainable management of land (Eswaran 1992). It will provide the scientific basis for evaluating the environmental impact of proposed land use changes and can be used for evaluating the consequences of projected global climate change.

Research on land has traditionally been driven by agricultural imperatives and though these are still important, ecological concerns resulting from the environmental problems that challenge human society (Conway 1987) are increasing. The finite land resource is stressing the carrying capacity of both humans and livestock. In developing countries, the situation is compounded by the absence of adequate assessments of the resource base and an absence of appropriate resource monitoring systems. Knowledge of the resource base and research to ecologically manage it are the foundations for informed policy decisions on its use.

All work on global resource assessments, specifically with respect to global environmental monitoring, is hampered due to lack of data. At the other end of the problem, farm level data needed to transfer technology are also absent in most developing countries. Due to this information gap, simulation models and decision support systems cannot be effectively used in most developing countries.

Agrotechnology transfer to developing countries has generally had mixed success. Germplasm transfer has been more successful wehereas land management technology has encountered obstacles. Part of the reason has been the inability to

mesh scientific technology with conventional farming practices. Acceptance is generally greater when farmers have participated in the technology development process. Thus, a major challenge is still the ability to involve farmers in the technology development and implementation process. A major information gap relates to methods and guidelines utilizing local farmer's knowledge and terminology as much as possible, to generate farm level soil resource information to enable extension workers to assist farmers in soil management.

Use of observable indicators and low cost assessments will enable the quick detection of unsustainability. The computer based counterparts of these will enable scientists to make similar assessments but with larger and more sophisticated databases.

Decision Support Systems

Technology transfer demands changes, not only in the way materials and people are used in production, but also in the way information is managed. Decision makers, in particularly environmentally-sensitive countries with limited natural resources, are expected to make technical decisions that are ecologically, economically, and socially acceptable (IBSNAT 1993). Agenda 21 of the Rio Conference in 1992 emphasized this. The information sources for making such decisions must be easily available, organized, timely, accurate and dependable. One approach for structuring and judging the value of information for decision making is a "decision support system (DSS)" such as the Decision Support System for Agro[illegible]ology Transfer (IBSNAT 1993). An example of a DSS with emphasis on soil [illegible]nate resources is that being developed by the World Soil Resources of the USDA Soil Conservation Service which is referred to as 'Biophysical Resource Appraisal Support System – BRASS'. BRASS integrates modern sources of information so that a 'user' can confidently make strategic and short-range decisions. BRASS is the result of an expanding computer industry which increasingly offers the decision maker more electronic sources of information. A fully-developed BRASS is a number of linked software packages that permits a user to access through his or her fingertips, global, state, and local sources of information for decision making. Needless to say, to evaluate each of these levels of decision making, appropriate data must be available.

If appropriate personnel in LDC[illegible] are assisted i[illegible]solving their common lack of reliable data relevant to th[illegible] purposes and scales, they will be strengthened in thier national to farm level decision making processes.

The justification for developing a decision support system such as BRASS is that timely and accurate information required for making better decisions and the database to support this process is not readily available. In addition, there are no systems that capture the wealth of information currently available. Many decisions are being made with minimal data, inappropriate data or data of low reliability. The user has few ways to determine the reliability (risk) of the proposed solutions. In addition to providing output to directly support a decision, the proposed BRASS also gives a measure of the risk associated with the output. This risk measure allows the user to choose the level of confidence he or she wants to be associated with a decision.

Another justification of research support for the proposed BRASS is its open

modular architecture which encourages third party development of databases and models, thus speeding the transfer of technical information. The modular structure of the BRASS also allows the core programs to run on a desk-top personal computer. These small computers are easily affordable by most users in developing countries. When fully implemented in the field, the proposed BRASS will represent a long-term investment by the user to ensure that the information needed for decision making will be up-to-date, timely and relevant.

We need to develop a 'scale-sensitive information system' because throughout society there is a vertical network of decision makers who have access to information which permits them to make policies concerning the use and distribution of resources. BRASS recognizes that decision makers at all levels of society must participate in the design and implementation of any tool that affects their social, economic, and ecologic well-being.

IMPLEMENTATION OF THE NEW AGENDA

Ecosystem-based Assistance

The need for a holistic and ecosystem based approach was emphasized by Conway (1987). Ecosystem Based Assistance (EBA) is a strategic initiative to ensure the enhancement of the quality of the ecosystem. It integrates biophysical, socioeconomic, and political considerations into relevant land use and management options to enable customers to make informed decisions on sustainable land use. It seems from the vision, 'a productive nation in harmony with a quality environment', which is the vision of the USDA Soil Conservation Service.

In this approach, not only the individual components of the system are given attention as in the past, but more importantly, the interactions between the components which have previously received lesser attention, are also considered. EBA will enable any agency committed to the sustainability of agriculture to provide ecosystem-based assistance that considers the spatial and temporal dimensions of technological interventions.

Ecosystem boundaries seldom match program legislation or political boundaries but EBA permits the design and implementation of any plan in the context of the ecosystem in which a site is located and thus, EBA is in a sense scale neutral. It also creates the awareness of the stakeholders to the larger ecological context of the on-site activities or the absence of such activities. It, in addition, assures a greater societal role in the management of a nation's resources.

Understanding of land resource systems holistically including the functioning and interactions of each of the components is *sine qua non* to sustainable land management and to reducing land degradation. The key to intergenerational equity, enhancing economic growth, and assuring sustainability depends on the following premises (Eswaran & Dumanski 1994):

- recognition that nature already has highly evolved processes of conversion, distribution, filtration, assimilation, and storage, and working with nature to perform these landscape functions is intelligent;
- acceptance of the fact that when parts of a landscape are manipulated for human needs, it impacts the whole ecosystem. Thus the processes and functions of each part and their linkages to the whole need to be under-

stood prior to exploitation;

- appreciation of the symbiotic relationships and interdependencies of landscape components and the fact that each of the functions (such as energy generation, shelter, water management, food production, and waste recycling) must be considered in totality for sustained use of the landscape;
- recognition that utilization of only one of the functions is tantamount to exploitation, resulting in degradation of the resource base, and that sustainability calls for seeking optimal levels for each of the multiple functions.

Incorporating the Stake-Holders

Research and development activities conducted without an active participation of the stake-holders have proven to have a short half-life. In the past the approach of concerned groups has been to 'reach-out' and the results have been mixed. The new agenda calls for scientists and decision makers to 'reach-in' so that customer participation becomes an integral part of both the research and development process. The underlying concept of this approach is to ensure a fair 'playing field' that ensures equal opportunity and equal access.

Sustainability and a reasonable management of the land resources will only result if the land-users are empowered and participate in the decision making process that institutes changes (Greenland *et al.* 1994). This participatory process is slow and laborious but if the stake-holder is not convinced that the proposed change is right for him/her, the farmer's cooperation is not assured. The desired results can be attained if ecological, economic, and social sustainability along with their interactions are considered and addressed. The goals of each are conflicting and to the average farmer of the third world, they may not appear to be interlinked. A pragmatic approach of the decision maker should not be to maximize each item but to attempt a balanced approach.

A Sustainable Land Management Facility

The ideas and needs expressed in this paper have been mentioned by others. Many third world countries are strongly impacted by not only a lack of assessment and monitoring facilities but also by a lack of institutional capability to undertake the needed land management work. Many of these countries have dedicated individuals who themselves are hampered by an absence of facilities to benefit from recent advances and lack of opportunities to interact with their peers. For these and other reasons, there is an urgent need to establish an international facility which not only serves as a clearing house to service scientists around the world in information dissemination and human resource development but also aids in developing the linkages between scientists of developed and developing countries.

CONCLUSIONS

This paper has advocated the need not only for an ecosystem based approach but also an ecosystem based assistance program to be practised by all nations. It also advocates a participatory approach to implementing ecosystem management. In the past too many decisions have been made as 'political decisions'. The new

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Agenda requires a strong science-based approach, an important component of which is a good understanding of the land conditions and of the consequences of management. Assessment, monitoring, and the use of reliable, cost-effective indicators are essential.

The implications of this new Agenda are that:

1. a change in manner of operations is due in all sectors of society;
2. institutions must reorganize to work on this new paradigm; they must retrain staff to think holistically and develop research programs to develop the science of ecosystem management;
3. stake-holders must be accepted as important participants in the process; they also need training and awareness to contribute; in addition, all levels of society must be willing to contribute to this quest of sustainability;
4. greater pragmatism is required from national decision makers who must subscribe to a new land ethic, an ethic designed to safeguard ecological sustainability and biological diversity while simultaneously ensuring the economic productivity potential of the nation; and
5. a national commitment to protect and preserve the land resources requires that assessment and monitoring is an integral activity of any sustainable land management program.

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