Draft Note

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Science Forum
CGIAR Priorities: Science for the Poor

INTEGRATED LAND, WATER AND FOREST MANAGEMENT AT LANDSCAPE LEVEL

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A recent effort by the Science Council to set priorities for CGIAR research to 2015, has identified five priority areas among which, poverty alleviation and the sustainable management of land, water and forest resources is one of them.

Focusing Beyond the Level of Individual Households

Utilization of natural resources is mostly carried out by individual managers who make decisions on-site, at the household scale, which in rural areas affect a specific field or the whole farm. Such decisions determine the productivity and sustainability of their enterprises, whether the enterprise consists of exploiting a small area inside a natural forest for subsistence, or a commercial farm. It is well recognized, however, that management interventions, in particular those related to natural resource use, have effects that go well beyond the individual field or the farm scales. Because such effects largely influence resource availability, conservation, and use by other members of society, it has become increasingly important to analyze and consider the management of land, water and forests at scales that go beyond above individual households, from the landscape up to the global level.

In this paper, the analyses and discussion are centered on the landscape level. Rather than attempting to define what is meant by landscape level, a discussion that, in my view, would end as a subject of academic rhetoric, the analysis will concentrate on outlining the concepts and ideas underlying the rational management of natural resources (NRM) as well as the unresolved issues that should be the subject of future research, all focused beyond the scale of an individual household.

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Attempting to Integrate All Components of Natural Resources Management

Many changes occur as one moves from the individual farm up to the landscape level, but there is one in particular that changes the nature of the approach and of the science needed to address management problems. That is the presence of more than one human being as the key actor in the decision-making process. The human factor with its multifaceted components: economic, social, political, institutional, and cultural, interacts with the biophysical components of the ecosystem in multiple ways. The complexity that results from such interactions is often so daunting, that it prevents reaching rational solutions to the problems faced in NRM. The challenge is **to integrate** all the relevant facets of each problem in the problem-solving approach that is followed, from problem identification to the implementation of solutions. There have been many attempts to develop integrative approaches to NRM, and the CGIAR has been in the forefront of many during the late 90's. Several important contributions on integrated NRM (INRM) emerged from such efforts[2]. A number of examples have been described[3], where INRM has been used to address a multiplicity of problems by integrating knowledge across scales, components, disciplines, and stakeholders.

While the harmonization of productivity objectives with those of environmental protection should be the ultimate goal of sustainable INRM, such a goal has been very difficult to achieve so far. Considering the bio-physical components, one major reason for that difficulty is the very limited knowledge that exists relating the consequences of management practices at the plot and farm scales to the behavior and the fate of land, water, and chemicals at the landscape levels. Knowledge limitations are not scientific, for the most part. The developments in environmental physics and in ecology in recent decades allows for the quantitative description of the many processes involved in environmental management. What is now needed is to integrate all the scientific knowledge developed in recent years into technological packages that will provide the managers with new means of optimizing resource use at the various scales. Simulation models, decision support systems (DSS) and tools for spatial characterization (remote sensing) and analysis (geographical information systems, GIS) constitute the weaponry used nowadays to tackle the various problems in land, water and forest management.

One important issue now is to what extent INRM is perceived by CGIAR scientists as the most appropriate research approach for the management of land, water, and forests in a sustainable fashion. Is the INRM paradigm sufficiently defined? Are INRM frameworks operational and useful enough to design and carry out problem-solving research? How to strike the right balance between the biophysical and the social sciences to make progress faster with INRM than with alternative, more disciplinary approaches?. Some of these questions must be answered in the context of the CGIAR research priorities defined recently by the Science Council.

[2] Sayer, J. A. and B. M. Campbell, 2001. Research to integrate Productivity Enhancement, Environmental Protection and Human Development. Conservation Ecology, http://www.consecol.org/vol5/iss2/art32/ . CGIAR, 2003. Research Towards Integrated Natural Resources Management. (R.R. Harwood and A. Kassam, eds.) 168 p.
[3] CGIAR, 2003, ibidem.

Adopting a Pragmatic Approach: Adaptive Management.

Dealing with the complexities of managing natural resources at the landscape level involve such a large number of interactions and relationships among system components, often highly non-linear in nature, that it is extremely difficult to predict impacts resulting from management interventions. As a result, a 'learning while doing' approach has been advocated as a dynamic process called adaptive management[4]. The adaptive management process starts with a decision based on the best information available, followed by implementation, feedback, and a readjustment based on what has been learned from the original intervention. Rather than managing the system using a rigid framework, the alternative strategy is to treat management as an ongoing process that updates knowledge continuously and reacts to changes dynamically.

There are a number of situations where adaptive management appears best suited. There are very complex systems at the higher scales, with many stakeholders who have different and conflicting goals. In other situations where information about system performance is meager or imprecise, which is common in many developing countries, adaptive management is the best option for INRM. River basins are complex systems where adaptive management approaches have been used successfully, as in the case of assessing the environmental flows in the Murray-Darling basin of Australia. The challenge is to combine empiricism with analytical models that can respond to observed changes, thus providing robust adaptive management frameworks. When conflicting interests arise, the decision-making process should be based on: a) identification of tradeoffs; b) making choices; c) decision and implementation policies, and d) having contingency plans to respond to feedbacks. Most importantly, all should be done with the **equitable participation of informed stakeholders**.

The Big Picture: Managing Land and Water for Sustaining World Food Supply.

World food production *per capita* has increased over the last 40 years by about 20% despite a 70 % increase in population. The productivity-enhancement research that led to such gains was not paralleled by sufficient research on how to manage soils and water to sustain indefinitely high production levels without harming the environment. Furthermore, it appears that there is considerable uncertainty in the current projections that predict continuing food security and affordable food prices for the future. The reasons for uncertain projections and, consequently, for the threats to sustainable food security, include deviations from the anticipated production trends in major crops, changes in land degradation rates, increasing water scarcity in agriculture, global climate change and increasing diversion of foodstuffs for renewable energy production. Additionally, the uneven distribution of food is the major cause for the persistence in numbers of hungry people, currently close to 800 million and primarily located in rural areas. In what ways does the management of land, water and forests alleviate poverty and hunger of these human beings?

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[4] Walters, C.J. 1986. Adaptive Management of Renewable Resources. Macmillan. New York. 374 p.

The State of Land Resources and Degradation

It is difficult to determine what is the situation with respect to land use and degradation, but some recent assessments provide a basis for concern[5]. The salinization of soils due to poor irrigation management is now extended to rainfed agriculture, with a speed and at a scale that affects large areas in Australia. In many parts of the Sub-Saharan Africa, different levels and causes of soil fertility decline are found. More than 2M ha are lost every year to cereal production due to urbanization and, also, to a shift to other crops. Nevertheless, in the long run, the confusion created by confounding, at the global scale, the risks of degradation or desertification with the actual processes, may hurt efforts to solve these problems. This is particularly grave because those risks unfortunately materialize in the marginal areas of Africa and some parts of Asia, inhabited by the poor.

Because the rate of soil formation is so slow, it is important to acquire accurate information on the rate and intensity of soil degradation in various ecosystems. It is also important to determine the soil erosion rates as affected by management practices and the relations between crop productivity and the different forms of degradation and erosion. There is little doubt that there are many causes and effects that threaten the land resource, from climatic (drought, rainfall patterns) to over-use of the land in agriculture or grazing, to nonpoint source pollutants, as well as socio-economic, cultural and institutional factors (high population growth, poverty, lack of access to education, bad policies, etc..). Progress in remote sensing techniques has been very significant over the last decade[6] (Ustin, 2004) and it is now possible to characterize land resources with high spatial resolution imagery that provide sufficient detail for diagnosis of many of the problems cited above. Tools for monitoring and surveillance of soil degradation problems are now feasible and reliable at several scales.

A quiet revolution in soil management techniques has been taking place recently with conservation tillage being extended and adopted widely in many World areas. Other aspects of conservation agriculture known for a long time, are being incorporated to maintain or improve soil quality, an essential feature of sustainable agriculture. One case where research and extension were combined to incorporate soil conservation practices into organic olive oil production in mountainous areas will be presented.

Managing Forests more Sustainably.

Managing complex forest ecosystems is a difficult task. Use of the adaptive management approach with stakeholder participation is now recognized as the basis for community-based forest management. The livelihoods of many poor people in the tropics depend on the sustainable management of their forests. Here, the social component of the needed science becomes even more relevant, as recognized in the

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[5] Penning deVries , F.W.T. et al., 2003. Integrated Land and Water Management for Food and Environmental Security. Comprehensive Assessment Research Report no. 1. IWMI. Colombo, Sri Lanka. 74 p.
[6] Ustin, S. L. (Ed.) 2004. Remote Sensing for Natural Resource Management and Environmental Monitoring. J. Wiley, NY. 736 p.

core activities of CIFOR[7]. Policies to protect the forests from overexploitation are crucial for the poor, who could become shareholders of common forests, and obtain employment or exploit non timber forest products while protecting the forest. In addition to the emphasis on livelihoods, sustainable forest management is more sensitive to the impact of logging operations, particularly in fragile ecosystems; aims at the maintenance of diversity and of ecosystem integrity; and orients management to include a broader range of services provided by forests, such as recreation or carbon sinks.

The climate change issue is particularly relevant in forest management. The key elements and processes of forest ecosystems must be known in areas where changes in the rainfall regime will threaten the viability of forests. Some fundamental responses to climate change in terms of forest water use need to be assessed, and more importantly; how to manage forests in the face of uncertainty? Again, DSS with multicriteria optimization models and RS and GIS tools will be key to delineate scenarios and to provide answers within an adaptive management framework.

Sustainable Water Management and Conservation

It should be stressed at the outset that water cannot be managed in isolation from the land or from the ecosystems under consideration. In fact, unifying land and water management should be high in the research agendas. At the landscape level, water should be evaluated within the boundaries of a watershed, catchment or river basin. River basins are of central importance to human activity and provide for the maintenance of terrestrial and aquatic ecosystems. Failure to preserve the quality and quantity of water in river basins could lead to significant impacts on human welfare and potentially irreversible effects on ecosystems. As with land or forests, benchmark watersheds can be used for water management research, providing “natural laboratories” for a common scientific framework and for comparative analyses.

It is desirable to focus water management research at the interfaces, interactions, and system feedbacks in an integrative fashion. Issues that are relevant on the biophysical aspects include long-term forecasting for water resources management (climate-land-groundwater interface), surface-groundwater interactions (river-aquifer interface) or the management of limited irrigation water (plant-soil-atmosphere interface). On the social side, water is perceived today by society as a key issue that is crucial for the judicious management and preservation of the environment where life takes place. Issues of water allocation, water quality or local placement of facilities, are becoming more complex, uncertain, and less tractable. The challenge is to provide institutions that, at the same time that they generate the regulatory policies, can facilitate the type of adaptive management research needed to address these problems.

Of all human activities, agriculture is by far the one that uses the most of the renewable water resources. Furthermore, a good fraction of agricultural use is consumptive, while most urban and industrial uses are basically not consumptive. Recent intensification of

[7] CIFOR, 2004. Forests for People and the Environment. Annual Report. Bogor, Indonesia. 69 p.

agriculture in response to the increased demand for food, has raised the risk of deteriorating the quality of the water not used consumptively that returns to the system. Thus, at the basin scale, agriculture is the activity that impacts the most on the availability and on the quality of water for other uses. The interactions and conflicts between irrigated agriculture and the environment are rooted in the competition for water between food production and nature. The reasons for conflict include, first, that irrigation development occurs in regions of scarce water resources. The substantial crop water requirements under irrigation usually represent the lion's share of such resources, leaving limited volumes for other sectors. Finally, the storage and diversion facilities that form the basis of irrigated agriculture cause fundamental changes in river hydrology and in the landscape, changes that have deep effects on ecosystems and that are increasingly challenged by segments of society.

Advances in Irrigation Management: Beyond the State of the Art

Starting at the regional level, the presentation will illustrate the current trends in irrigation management in several areas of limited water resources. Strategies of crop diversification, water users associations and water markets are being used to mitigate the effects of periodic droughts that appear to increase in severity, due to greater demands on the same water supply. Work at the irrigation district scale will be outlined to demonstrate that faster and inexpensive computers and user-friendly interfaces can put sophisticated modelling within the reach of district managers around the world. The combination of biophysical and economic models provides answers to the question most often asked in a water shortage situation: How to best use a given water volume over the whole irrigation network?

Scaling up the process of irrigation over a field and beyond introduces the heterogeneity of various system components. There is spatial variability in soil water properties, in the uniformity of irrigation water distribution; in crop growth and in the depth and density of root systems, and, finally, in the presence and concentration of salts and other chemicals. Some variations may be predicted, such as those introduced by the use of micro irrigation systems or by the patterns of nutrient application. Others require spatial analyses and feedbacks to characterize and predict the behavior of the system at the watershed scale. Such analyses are becoming economically feasible without resorting to field surveys by the use of remote sensing techniques. Until now, however, such techniques have been used for planning rather than for management purposes, as the frequency of satellite-based information is insufficient to provide feedbacks that would be useful in management decisions. The use of airborne sensors at frequent intervals offers the needed feedbacks for improving management decisions on-farm, as well as the critical connection between specific irrigation activities in various locations and the water and chemical flows leaving the watershed.

Finally, in many situations irrigation is no longer managed to remove the water constraint on crop production, but to optimise the productivity of a limited amount of water via deficit or supplemental irrigation. Tools and methods being developed will be discussed, including economic and institutional analyses for irrigation decision-making