Conserving Land, Protecting Water: an Introduction

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Much work has been carried out to understand the state of our global resources. A recent series of international assessments has alerted the world to climate change (IPCC, 2007), ecosystem and environmental degradation (MEA, 2005), water scarcity (Molden, 2007), and natural resource degradation (GEO, 2007). These reports indicate that agricultural practices are partly responsible for damage to the global environment. An understanding of the processes related to these assessed impacts is, however, more dispersed and fragmented, and less available are analyses that link land and water resource degradation, as well as those that integrate land and water degradation with an analysis of socio-political and economic contexts.

This volume follows from a project of the Comprehensive Assessment of Water Management in Agriculture that brought together experts in fields ranging across the social sciences, ecology, agricultural sciences, soil and water science, political science and development studies to examine examples of success in reversing land degradation, understand their importance, and explore the essential relationships and linkages between land use and water management within them. This book aims to improve our understanding of these linkages, and examines the relationships between land, water and social systems, emphasising that it is only such an integrated view that will yield a better understanding of how positive outcomes can be generated.

At the heart of this book lie three main messages. The first of these is that success stories of reversing or mitigating land degradation do exist, and that a great deal can be learned from these.

The second key message is that the key to effective water resources management is understanding that the water cycle and land management are inextricably linked: that every land-use decision is a water-use decision. Gains in agricultural water productivity, therefore, will only be obtained alongside improvements in land-use management.

Expected increases in food demands by 2050 insist that agricultural production – and agricultural water use – must increase. At the same time, competition for water between agricultural and urban sectors will also increase; competing demands, such as biofuel production, will reduce land and water availability for food production; increasing water resource contamination will reduce effective water availability; and climate variability will increase risks in many production systems. As a consequence, it is predicted that by 2025, most developing countries will face either physical or economic water scarcity. These pressures and problems are further compounded by land degradation. Soil erosion, nutrient depletion and other forms of land degradation reduce water productivity and affect water availability, quality and storage. Tackling human-induced degradation of agricultural land is therefore central to addressing the 'water crisis'. Reversing these trends entails tackling the underlying social, economic, political and institutional drivers of unsustainable land use.

The third key message in this book is that all resource use is contextualized ('embedded') within social, political and economic systems that affect profoundly the ways in which water and land are used. An analysis of water–land interaction is, in many respects, incomplete

without an understanding of the social systems that govern it. Land degradation is driven by the complex socio-political and economic contexts in which land-use decisions are made and land use occurs. Thus, this book aims to integrate both social and physical perspectives, and argues that both social and biophysical systems can be manipulated in such a way as to yield excellent land and water conservation results, and where this happens, we encounter 'bright spots'. A failure to address both social and biophysical drivers at the same time, we believe, will not yield bright spots.

An analysis of the impacts of land degradation on water cannot be divorced from the issue of poverty. The rural poor in developing countries suffer the most directly from land degradation and are the most vulnerable to the pressures on water availability and access. The poor are clustered on the most degraded and fragile land, and because such land is also often very vulnerable to climatic factors such as drought or flooding, poverty can be compounded as a consequence. Risk avoidance is costly, and in order to reduce the duration over which these costs are incurred, small-scale farmers may choose to intensify their land-use practices at the expense of land sustainability, contributing further to land degradation. For these people, land degradation has direct negative impacts on health through malnutrition, and increases the amount of labour required per unit of agricultural output. Thus, this book emphasises land degradation and its solutions in developing countries, where the ability of the poor to 'mask' land degradation (through, for example, the application of fertilizer) is minimal, and where success stories are therefore all the more remarkable as a consequence.

This book set out to do three things. First, to advance an understanding of the essential linkages between land and water management and how social systems and politics affect land use. Secondly, to put forward in a single volume a variety of promising trends in both the social and physical sciences related to reversing degradation. And thirdly, to present a global compilation of case study evidence for the gains that can be made by reversing current trends in resource degradation. This book is part of a nascent trend of looking for positive examples of sustainable use of natural resources, and is aimed at the non-specialist scientist. It places these success cases within the context of global discourses on the environment and its degradation. These ideas and the work presented are of considerable relevance to increasingly difficult development conditions, and substantial confusion surrounding the directions which development should take. Given that the mainstay of most developing country economies is agriculture, this volume will provide innovative and occasionally provocative ideas for the prevention of land degradation and for improving the sustainability (in both economic and environmental ways) of food production in the developing world.

The book's first section briefly reviews the literature on the status of the world's ecosystems with respect to land and water resources and global patterns of land and water degradation, and then focuses on newer insights into how we view the impact of degradation, the essential linkages between the management of land and water, and the social processes that determine land-use decision making and their interaction with land degradation. The second section of the book explores improved management options, both in theoretical contexts and through practical case studies focusing on the integration of land and water within social contexts and management frameworks at larger scales. Section three presents in detail a large compilation of successful case studies gathered under the 'bright spots' project. We look at the aggregate impact of these innovative solutions on reversing soil and water degradation and their impact on food and environmental security. We also explore the driving forces and necessary conditions that were essential for their success.

Part I: Emerging Issues

Trends in land degradation

Major trends related to land degradation and agricultural productivity globally include:

1. Loss of water for agriculture and reallocation to cities and industries.
2. Reduction in land quality in many different ways, leading to reduced food supplies, lower agricultural incomes, increased costs to farmers and consumers, and a deterioration of water catchment functions.
3. Reduction in water quality due to pollution, water-borne diseases and disease vectors.
4. Loss of farmland through conversion to non-agricultural purposes.

In Chapter 1, Penning de Vries *et al*. introduce these issues and then analyse degradation processes in relation to four major zones: headwaters, plains, urban areas and coastal areas, which cover five ecosystems. The processes and their management are quite different amongst these zones and systems. The important issue of urban impacts on land and water degradation in the form of large-scale nutrient fluxes is elaborated in more detail in Chapter 5. Here, Frits Penning de Vries points out that, on average globally, only half of the nutrients that crops take from the soil are replaced, and the removal of the other half slowly depletes the soils, often to levels where productivity becomes impaired. Nutrients contained in harvested products and in food flow from farmland to settlements, and from rural areas to cities. Most of the nutrients in food consumed in cities are neither recycled nor otherwise re-used, but either accumulate unproductively or pollute rivers and seas. Urbanization, international trade and negligence of the environmental cost of soil nutrient removal reinforce this process.

Land degradation and water productivity

The potential gain in water productivity through land management interventions, particularly to improve soil quality, is large and underappreciated. In Chapter 2, Bossio and colleagues review various studies, which estimate that water productivity in irrigated systems can be improved by between 20 and 40%, primarily through land management approaches. In rainfed systems in developing countries, where average crop production is very low, and many soils suffer from nutrient depletion, erosion and other degradation problems, potential improvement in water productivity is even higher, and may be as high as 100% in many systems. When these gains are achieved by reducing unproductive losses of water (primarily evaporation) or increasing transpiration efficiency, they represent water productivity gains at even larger scales than the farm. This potential for improvement is higher than that which can be expected through the genetic improvement of crops or water management alone in the near future. The mitigation of land degradation is therefore central to increasing water productivity and thereby preserving both terrestrial and aquatic ecosystems and their accompanying services.

One vehicle to help boost investment in reversing land degradation that has received much attention is potential payments for carbon sequestration, which may now occur through international treaties. In Chapter 6, Trabucco *et al*. present a global analysis that assesses the potential of the Kyoto Protocol Clean Development Mechanism afforestation and reforestation (CDM-AR) projects to impact water use and to mitigate land degradation. Carbon sequestration in terrestrial ecosystems is one of many climate change mitigation measures that have been incorporated into global treaties that aim to stabilize atmospheric carbon dioxide concentrations at a level that avoids dangerous climate change. This treaty will affect land-use decisions, by providing incentives for afforestation and reforestation in developing countries. This has been seen as a potential boon for sustainable development and reversing land degradation. The chapter presents an evaluation of the potential to address land degradation through CDM-AR projects, and makes it clear that the current scale of CDM-AR implementation is wholly inadequate to address the severity and scale of ongoing global land degradation processes. It is likely, however, that carbon sequestration payments will play a larger role in the future. If this occurs, targeting land degradation, and

designing for positive water-use outcomes when planning projects, could significantly improve the environmental outcomes of such international treaties.

Social processes

Human-induced land degradation occurs within social–political contexts that affect the decision making of the land users. In Chapter 4, Geheb and Mapedza propose that resource management is not about managing individual resources, but rather about managing people. Decision making on land use is affected by politics and power at many levels. Up and down the chain, from household to national and global scales, these interactions serve to influence institutions and associated entitlements in ways that may not be desirable for ecological sustainability in the long run. At the most localized, the competition between men and women in a household determines resource-use decisions, while at higher levels increasingly powerful institutions govern decisions and, hence, the ways in which resources are used. Understanding these relationships is fundamental to understanding land-use decisions and thereby influencing them towards improved resource use. In many cases, institutions at higher levels actually interfere with sustainable resource use, by taking the access and decision-making power away from those who understand best both the resources and what they need from those resources. The global economy also has enormous influence on political systems that affect the way resources are used and managed. Geheb and Mapedza describe the roles of power, leadership, corruption and institutions, and present examples of ways in which these trends might be manipulated to yield positive outcomes. They suggest that lack of interference by external powers, leadership, and access to new ideas and knowledge are all essential prerequisites to the localized development of bright spots; they are also, they argue, inherently political prerequisites.

Geheb and Mapedza also make the point that environments and their resources are more or less completely integrated into social processes determining their use – and, therefore, conservation. This point is reiterated by Gordon and Enfors, who link resource conditions with social processes in a discussion on social–ecological 'resilience' and how it is affected by land degradation. In Chapter 3, they focus on 'agro-ecological landscapes'. These are landscapes that are heavily modified by human activities, mainly to increase the production of provisioning ecosystem services, such as food, fibre, fuel wood and fodder. These landscapes can include pockets of smaller ecosystem reserves, but most of them are heavily manipulated by human activities. This means that the ecological processes in these areas are primarily a social endeavour, shaped by human values and policy decisions. The emerging understanding of social–ecological systems focuses on the coupling between social development and ecological support capacity. Understanding the institutions, norms and rules that guide human behaviour in response to ecosystem behaviour is central to understanding and encouraging resilience in social and ecological systems. Chapter 3 focuses particularly on the feedbacks between local to national institutional changes and changes in the local resource base, both as perceived by farmers and as detected by different biophysical indicators.

Part II: Towards Better Land and Water Management

Local-scale initiatives

Technological solutions to land degradation at the field scale are well understood. Terraces can reduce erosion from sloping lands; mulching can reduce unproductive evaporation; fertilizers can replace lost nutrients; integrated pest management can reduce agricultural chemical pollution; and drainage can be used to reduce salinization of irrigated land. But despite this knowledge, human-induced degradation of resources continues and may even be accelerating. In this section, we provide both theoretical and practical insights into areas that are not as well understood but which are important for moving towards improved land and water management. These are the integration of land

and water within social contexts and management frameworks at larger scales.

Indigenous environmental knowledge as the key to improved rainwater management in drought-prone areas and the phenomenon and importance of urban agriculture are highlighted in Chapters 7 and 8. In Chapter 7, William Critchley and his colleagues argue that indigenous environmental knowledge is essential to improved 'green water' management in drought-prone areas of the tropics. The traditional and innovative technologies described in the chapter comprise eight technology groups: mulching, no-till farming, homegarden systems, terraces, live barriers, gully gardens, forms of riverbank protection, and water-borne manuring. Some of the practices are well known and documented already – others are relatively novel or interesting variations on a theme. Certain common themes run through these technologies. The integrated management of land and water is one, and the creation of micro-environments is another. Water is a key component of innovation: valued as a productive resource, it is also used strategically to move soil and manure. Innovators often create names for their products, and slogans for their principles. Multiple innovation by one person and 'parallel innovation' by people far apart are often witnessed. Travel (a point also raised by Geheb and Mapedza) evidently stimulates the imagination. At a more pragmatic level, innovation is commonly triggered by a desire to escape from poverty, and thus rural innovation is usually linked to production and profit. The route to taking such innovative thinking and practices forward, Critchley *et al*. argue, is in methodological approaches that involve seeking out innovation, stimulating it, 'adding value' through collaboration with researchers and then using a form of farmer-to-farmer extension to propagate it.

In Chapter 8, Dreschel, Cofie and Niang discuss a particularly successful farming system: irrigated urban agriculture, which is driven by market opportunities that support quick and tangible benefits. Urban agriculture is widely practised in sub-Saharan Africa, and involves more than 20 million people in West Africa alone and 800 million worldwide. Dreschel and his colleagues focus on the open-space production of high-value products on undeveloped urban land, particularly the widely distributed system of irrigated vegetable production. They both demonstrate the potential of this system to feed Africa's rapidly growing urban areas, and analyse its sustainability according to economic, environmental and social criteria. Their analysis draws attention to the need to consider ways in which to diminish the health threats posed by irrigating vegetables with wastewater, which is a common feature of urban agriculture. Because much urban agriculture occurs on private land where tenure is insecure, and urban farmers face the constant risk of ejection, Dreschel and his colleagues call for a legalization of the practice, and its encouragement by African governments, as one means of tackling eviction risks and the health problems associated with this farming system.

These problems of legitimacy are not uncommon in the developing world, where large investment solutions are often favoured over small-scale initiatives that work well within local environmental and social contexts. In the latter case, these initiatives are often disregarded as backward, or unlikely to yield the kinds of outputs deemed necessary to push a nation from underdeveloped to developed. In Chapter 9, the potential of these small-scale initiatives is further explored through the experiences of one international effort, the World Overview of Conservation Approaches and Technologies (WOCAT). WOCAT's mission is to support decision making and innovation in sustainable land management by connecting stakeholders, enhancing capacity, developing and applying standardized tools for the documentation, and evaluation, monitoring and exchange of soil and water conservation knowledge. The database currently contains descriptions of 374 technologies and 239 approaches. This long-term data collection exercise reveals that a new set of objectives is emerging in soil–water conservation interventions: to address the rapidly emerging global environmental concerns of preserving biodiversity and mitigating climate change through carbon sequestration (as elaborated by Trabucco *et al*.), and new marketing opportunities which may change the way soil and water conservation initiatives are viewed and supported. Liniger and Critchley

emphatically demonstrate (Chapter 9) that such soil and water conservation techniques contain the potential to not only transform rural livelihoods but also whole landscapes, by mitigating or preventing land degradation. They argue that the cases documented in the WOCAT database demonstrate the value of investing in rural areas despite recent global trends of neglecting agriculture and focusing on industry and the service sector.

Landscape and basin scales – physical and social

Bright spots are described most at farm or community levels, and it is assumed that their scaling-up will result in a better situation for all. Examining bright spots using a basin perspective brings out some of the issues and questions associated with their scaling-up that are not obvious at smaller scales. A bright spot in one location may cause problems elsewhere in a basin, if, for example, runoff is diverted upstream, and downstream water users suffer. Conversely, a bright spot upstream can also benefit downstream communities, by resulting in better regulation of water flows and provision of cleaner water. To more effectively contribute to addressing basin-wide land degradation challenges and to enhancing total net benefits equitably and sustainably, it is necessary to understand bright spots in the basin and not only on the farm or in the community. In Chapter 10, Gichuki and Molden develop an analytical framework to improve our understanding of the complex interplay between local bright spots and water-related externalities and of options for optimizing basin-wide bright spot benefits. They use this framework to better understand how bright spots and their externalities have been managed in four case study areas. It is notable, in Chapter 10, that the success of the case studies discussed has arisen from interventions intended to address meso-scale externality problems – and not necessarily arisen as a consequence of a multitude of local-level endeavours building up into a meso-scale success story. This issue hints at the problems associated with propagating bright spots' successes across scales.

One recent initiative that is of considerable importance in this respect is analysed in Chapter 11. In order to develop strategies for sustainable water management in landscapes, one must grasp the system relationships between climatic constraints of water balance, the patterns of the main water fluxes in landscapes, including the kinetics of water cycling and recycling, and its uptake for human demands. In addition to conventional infrastructural and technical approaches, there are new options for water storage and recycling, provided by recent advances in landscape ecology. In this Chapter, Lech Ryszkowski and Andrzej Kęziora present progress in landscape ecology concerning the influence of plant cover structure on water cycling. The modification of the water cycle by plants had not, until recently, been factored into water management strategies. What Ryszkowski and Kęziora show is that evapotranspiration and surface and ground runoff are strongly influenced by changes in plant cover structure. These influences go beyond differences in water use by various plant types (trees versus annual crops) to include microclimatic changes that occur due to plant cover changes. Shelterbelts, for example, cool the air and alter wind currents, and thereby reduce evapotranspiration by companion annual crops. Saving moisture in fields between shelterbelts, water storage in small mid-field ponds and water recycling within the watershed can increase water retention in landscapes. Thus, the manipulation of a landscape's plant cover can bring important changes in the water flow rate, which has a bearing on the ecosystem's functions.

In Chapter 12, Jules Pretty engages in a discussion of the importance of the social landscape in natural resources management. He reminds us that for as long as people have managed natural resources, they have engaged in forms of collective action, because resources, through their fluctuations, generate dilemmas, the solution of which is best achieved communally. Farming households have collaborated in water management, labour sharing and marketing; pastoralists have co-managed grasslands; and fishing families and their communities have jointly managed aquatic resources. It has, however, been rare for the

importance of such local groups and institutions to be recognized in recent agricultural and rural development. In both developing and industrialized country contexts, policy and practice has tended not to focus on groups or communities as agents of change, or of being in possession of the social capacity and tools to engineer such change. In large measure, these capabilities reside in the relationships between people in the same community – in networks. Pretty provides a series of case studies of how 'social capital' can yield remarkably successful resource management outcomes. He reviews the increasing number of studies that show that when communities are able to bring this capital asset to bear to solve a resource dilemma, and produce a sustainable managerial outcome, then agricultural and natural resource productivity can benefit in the long term. The challenge is to develop and encourage forms of social organization that are structurally suited for natural resource management and protection.

Part III: Bright Spots

This last section of the book summarizes results from the bright spots project in two chapters (13 and 14). The project set out to catalogue a large set of success stories in developing-country agriculture. These cases (covering 36.9 million hectares across 57 countries) demonstrated that, through a variety of resource-conserving agricultural practices, is it possible to increase both yields and food production while improving or maintaining the condition of natural resources. The cases analysed by Noble *et al*. in Chapter 13 resulted in an average increase in crop production of 80%, across a wide range of farming systems. Notably, smallholder systems showed the greatest gains in production, which is partly because many of these systems had been producing at levels far below ecological potential before the introduction of integrated resource-conserving practices. Noble and his colleagues identified leadership (*cf.* Geheb and Mapedza; Critchley *et al.*; and Liniger and Critchley), social capital (*cf.* Pretty), investment, and other factors as the key drivers behind the success of these cases. These successes are put into environmental context by Bossio *et al*. in Chapter 14, where they describe how local success in increasing productivity in agricultural systems can be translated into ecosystem benefits at local and larger scales when the agricultural technologies used are appropriate and mitigate land degradation. This latter chapter, then, links the findings from these case studies to important trends and thinking in ecosystem management, in which agricultural practice is seen as the key entry point for improvements in, for example, carbon sequestration (*cf.* Trabucco *et al*.), increasing water productivity (*cf.* Bossio *et al*. Chapter 2), and water cycling at larger scales (*cf.* Gichuki and Molden; Ryszkowski and Kęziora). It was notable in this analysis that those bright spots based on a diversity of interventions and which focused on the management of agricultural landscapes (rather than single fields) resulted in a wider range of ecosystem benefits than those that targeted only farm productivity goals. Multifunctional systems, in other words, provide a wider range of benefits.

Conclusions

This book has detailed the strong links between land degradation and water use and management. It has demonstrated that improved land management can be good for both agricultural livelihoods and water resources simultaneously. It makes clear that the mitigation of land degradation can result in significant increases in water productivity, and this can be achieved using existing technologies and approaches. Finally, it has demonstrated that the bright spots that result cannot occur without an understanding of the socio-political contexts within which they exist, and an appreciation of the social capital that has enabled the innovation to occur.

The need for more food over the next 50 years calls for agricultural intensification, and the growth of more food with less water. In order to achieve this goal, land degradation must be mitigated. This book calls for policy and local-level interventions that can stimulate resource-conserving agriculture that improves land and water productivity, and works with ecosystem

sustainability and contributes to it in the long term. In addition, the book calls for an understanding of land use at the landscape level, managing these as a suite of potential activities with ecosystems in common. Finally, the book calls for human societies to be recognized as integral components of these landscapes, the ecological trends that characterize them, and their successful management. In summary, this volume calls for the following to be recognized (Bossio *et al*., 2007):

- The key to effective management of water resources is understanding that the water cycle and land management are intimately linked. Every land-use decision is a water-use decision.
- Improving water management in agriculture and the livelihoods of the rural poor requires the mitigation or prevention of land degradation.
- Land degradation is driven by the complex socio-political and economic context in which land use occurs; the same is true of solutions to land degradation.
- Smallholder agricultural systems are an important intervention point for measures aimed at preventing or mitigating land degradation in the developing world.
- Integrated solutions that support participation in sustainable land management are needed to achieve balance in food production, poverty alleviation, and resource conservation.
- Enhancing the multifunctionality of agricultural land is a point of convergence for poverty reduction, resource conservation, and international concerns for global food security, biodiversity conservation, and carbon sequestration.

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