



# Managing Land and Landscapes

*A Sourcebook*

ADVANCE WEB EDITION



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## ACRONYMS AND ABBREVIATIONS

ADC Agribusiness Development Center  
ADPC Asian Disaster Preparedness Center  
ADS Agricultural Development Strategy  
AFR Sub-Saharan Africa region, World Bank  
AIN Agricultural Investment Note  
AKIS Agricultural Knowledge and Information System  
APL Adaptable Program Lending  
APL Adaptable Program Loan  
ASAL Agricultural Sector Adjustment Loan  
ASAL Agricultural Sector Adjustment Loan  
ASP Agricultural Sector Program  
AWS Agricultural water strategy  
B/C Benefit-cost (ratio)  
BCM Billion cubic meters  
BDS Business Development Services  
BNWPP Bank–Netherlands Water Partnership Program  
BP Bank Procedure  
BP Bank procedure  
CAS Country Assistance Strategy  
CAS Country Assistance Strategy  
CBNRM Community-Based Natural Resource Management  
CBO Community-Based Organization  
CDD Community-Driven Development  
CDD Community-driven development  
CDF Comprehensive Development Framework  
CF Conservation Farming  
CGAP Consultative Group to Assist the Poor  
CGE Computable general Equilibrium  
CGIAR Consultative Group on International Agricultural Research  
CGIAR Consultative Group on International Agricultural Research  
CGISP Community Groundwater Irrigation Sector Project, Nepal  
CIAL Comité de investigación agrícola local/local agricultural research committee  
CIDA Canadian International Development Agency  
CMS Cubic meters per second  
CRGP Competitive Research Grant Program  
CRMG Commodity Risk Management Group  
CT Conservation Tillage  
CWRAS Country Water Resources Assistance Strategy  
DALY Disability-adjusted life year  
DFID Department for International Development  
DIS Direct Income Support  
EA East Asia region, World Bank  
ECA Eastern Europe and Central Asia Region  
ECA Europe and Central Asia region, World Bank

EIA Environmental impact assessment  
 EPADP Public Authority for Drainage Projects, Egypt  
 ERR Economic Rate of Return  
 ESW Economic and Sector Work  
 ET Evapotranspiration  
 EU European Union  
 EU European Union  
 FAO Food and Agriculture Organization  
 FAO Food and Agriculture  
 FFS Farmer Field School  
 GCD Groundwater Conservation District  
 GDP Gross Domestic Product  
 GEF Global Environment Facility  
 GEF Global Environmental Facility  
 GIS Geographical information system  
 GMO Genetically Modified Organism  
 GWMATE Groundwater Management Advisory Team  
 HACCP Hazard analysis and critical control point  
 I&D Irrigation and drainage  
 I/O Input/output  
 ICID International Commission on Irrigation and Drainage  
 ICR Implementation Completion Report  
 IDA International Development Association  
 IFAD International Fund for Agricultural Development  
 IFC International Finance Corporation  
 IFPRI International Food Policy Research Institute  
 IIMI International Irrigation Management Institute.  
 ILRI International Institute for Land Reclamation and Improvement  
 IMT Irrigation Management Transfer  
 IRR Internal rate of return  
 ISC Irrigation service charge  
 ITRC Irrigation Training and Research Center  
 IUCN World Conservation Union  
 IWASRI International Waterlogging and Salinity Research Institute, Pakistan  
 IWDP Integrated Wasteland Development Program  
 IWEMP *Integrated water and environmental management plans*. IWEMPs  
 IWMI International Water Management Institute  
 IWSFM Integrated water and soil fertility management  
 LAC Latin America and Caribbean region, World Bank  
 LBOD Left Bank Outfall Drain, Pakistan  
 LIL Learning and Investment Loan  
 MCM Million cubic meters  
 MNA Middle East and North Africa region, World Bank  
 MODIS Moderate Imaging Spectroradiometer  
 OED Operations Evaluation Department  
 OP Operational Policy  
 PESW Programmatic economic and sector work  
 PIM Participatory irrigation management

PLC Programmable logic controller  
PRSP Poverty Reduction Strategy Paper  
PSAL Programmatic Structural Adjustment Loan  
R&D Research and development  
RAP Rapid appraisal procedure  
RWSS Rural water supply and sanitation  
SA South Asia region, World Bank  
SAL Structural Adjustment Loan  
SAM Social accounting matrix  
SCARP Salinity Control and Reclamation project  
SEBAL  
SECAL Sector Adjustment Loan  
SF Social fund  
SI Supplemental irrigation  
S-I/O Semi-input/output  
SIL Specific Investment Loan  
SIWI Stockholm International Water Institute  
SLM Sustainable Land Management  
SMI Small- and medium-scale irrigation  
SPFS Food Security Special Program, FAO  
SPS Sanitary-phytosanitary standards  
SSAL Special Structural Adjustment Loan  
SWAP Sector-Wide Approaches  
ULA Upper level association  
UN United Nations  
VDC Village development committee  
WARP Water Resources Action Program, Zambia  
WATSAL Water Resources Sector Adjustment Loan  
WRM Water resources management  
WRS Water Resources Strategy  
WUA Water user association  
WUAF Water user association federation  
WUE Water use efficiency  
WWF World Wildlife Fund

## OVERVIEW

Increased investment to promote agricultural growth and poverty reduction is a key objective of the World Bank's rural strategy, *Reaching the Rural Poor* that was released in 2003. One major component of the strategy outlines the priorities and the approaches that the public sector, private sector, and civil society can employ to enhance productivity and competitiveness of the agricultural sector in ways that reduce rural poverty and sustain the natural resource base. The pathways and possible actions involve participation by rural communities, science and technology, knowledge generation and further learning, capacity enhancement, and institution building.

The strategy commits the Bank to five core areas of rural development:

- Foster an enabling environment for broad-based and sustainable rural growth;
- Promote agricultural productivity and competitiveness;
- Encourage non-farm economic growth;
- Improve social well-being, managing and mitigating risk, and reducing vulnerability;
- Enhance sustainability of natural resource management.

Underlying all of the investments and actions is pro-poor agricultural growth with the specific aim of helping client countries reach the Millennium Development Goals, especially the goal of halving poverty and hunger by 2015.

While developing the new rural strategy, the need to better articulate good practice in agricultural policies and investments became clear. To support the rural strategy, the Agriculture and Rural Development department compiled and launched an Agriculture Investment Sourcebook and the Shaping the Future of Water sourcebook that document and highlight a wide range of emerging good practice and innovative approaches to investing in the agriculture and rural sector. Because good land management is essential for sustaining the productivity of agriculture, forestry, fisheries, hydrology (water), and it impacts a range of ecosystem services upon which the sustainability of agriculture depends; this sourcebook has been produced to complement the previous sourcebooks. The focus is on land management for enhanced production as well as ecosystem services (box 1).

### Box 1. Ecosystem Services

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Examples of ecosystems include natural forests, to landscapes with mixed patterns of human use, to ecosystems intensively managed and modified by humans, such as agricultural land and urban areas. Ecosystem services are the benefits people obtain from ecosystems for example:

- provision services such as food, water, timber, and fiber;
- regulate services that affect climate, floods, disease, wastes, and water quality;
- cultural services that provide recreational, aesthetic, and spiritual benefits; and
- support services such as soil formation, photosynthesis, and nutrient cycling.

The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services.

Source: [www.millenniumassessments.org](http://www.millenniumassessments.org)

Until recently, increases in agricultural productivity particularly in developed regions of the world (facilitated by both science and subsidy) have pushed world agricultural commodity prices down,

making it increasingly difficult for marginal land farmers to operate profitably within existing technical and economic parameters (Sachs, 2005). These trends may not be reliable pointers to the future.

### *Structure of the Sustainable Land Management Sourcebook and Guide to Users*

This Sourcebook is intended as a ready reference for practitioners (including World Bank stakeholders and clients in borrowing countries as well as Bank project leaders) seeking information on the state of the art about good land management approaches and innovations for investments, and close monitoring for potential scaling up.

This Sourcebook is divided into four sections:

- *Section 1* identifies the need and scope for sustainable land management (SLM) and food production in relation to cross-sector issues such as freshwater and forest resources, regional climate and air quality, and interactions with existing and emerging infectious diseases. This section introduces the concept of production landscapes and trade-offs analysis as well as a framework for linking indicators that provide a measure of the outcomes of SLM.
- *Section 2* categorizes the diversity of land management (i.e., farming) systems globally and the strategies for improving household livelihoods in each system type. For the farming system types, a set of SLM principles and common but important issues for future investments are identified.
- *Section 3* focuses on three major farming system types and presents a range of Investment Notes (INs) and Innovative Activity Profiles (IAPs).
  1. *Investment Notes.* Summarize good practice and lessons learned in specific investment areas, and provide a brief, but technically sound overview for the non-specialist. For each IN the investments have been evaluated in different settings for effectiveness and sustainability, and can be broadly endorsed by the community of practitioners from within and outside the Bank.
  2. *Innovative Activity Profiles.* Highlight design of successful or innovative investments. They provide a short description of an activity in the Bank's portfolio or that of a partner agency, which focuses on potential effectiveness in poverty reduction, empowerment, or sustainability. Activities profiled have often not been sufficiently tested and evaluated in a range of settings to be considered "good practice," but should be closely monitored for potential scaling up.
- *Section 4* provides users of the source book with easy-to-access, web-based resources relevant for land and natural resource managers. The resources are available in the public domain and users access the web-sites of various international and national agencies.

This Sourcebook provides introductions to topics, but not detailed guidelines on "how to" design and implement investments. Each IN and IAP has listed Selected Readings and Web Resources. These are provided for readers who seek more in-depth information and examples of practical experience.

This first edition draws on the experiences of various institutional partners that work alongside the World Bank in the agriculture and natural resource management sectors. Major contributors are



Research and Development (R&D) experts from the Consultative Group of International Agriculture Research (CGIAR) centers together with their national partners from government and non-governmental agencies. The diverse menu of options for profitably investing in SLM that is presented is still a work in progress. There are still important gaps that need to be filled, and good practice is constantly evolving as knowledge and experience accumulate. Our intention is to continue to harness the experience among the many Bank projects in all regions as well as the partners in other multilateral and bilateral institutions, national organizations, and civil society organizations. The Sections, Investment Notes, and Innovative Activity Profiles in this Sourcebook will be updated annually.

## **SECTION I: Sustainable Land Management: Challenges and Opportunities**

### *Overview*

Land-use activities—whether converting natural landscapes for human use or changing management practices on human-dominated lands—have transformed a large proportion of the planet’s land surface. By clearing tropical forests, practicing subsistence agriculture, intensifying farmland production, or expanding urban centers, human actions are changing the world’s landscapes. Although land use practices vary greatly across the world, their ultimate outcome is generally the same: (a) food and fiber production, and (b) the acquisition of natural resources for immediate human needs.

In the paragraphs below, we present the rationale for why SLM is a critical cross-sector driver for maintaining production and services from human dominated landscapes. The challenges identified are also entry points for carefully targeted interventions and represent opportunities for pro-poor investments.

### *Definition of Sustainable Land Management*

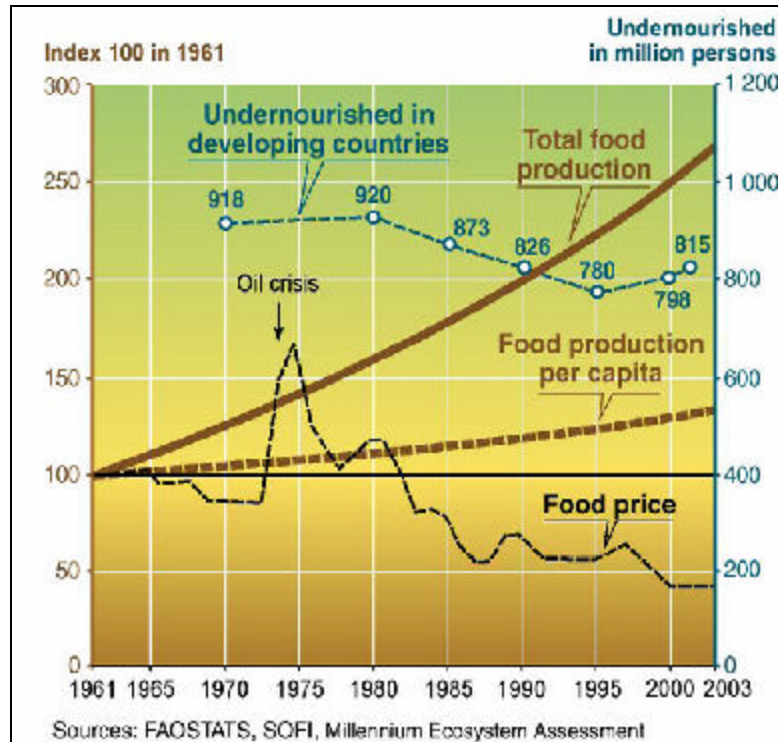
*Sustainable Land Management* is defined as a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (includes input and output externalities) to meet rising food and fiber demands while sustaining ecosystem services and livelihoods. SLM is necessary to meet the requirements of a growing population. Improper land management can lead to land degradation and a significant reduction in the productive and service functions (World Bank 2006).

In layman’s terms, SLM involves:

1. Preserving and enhancing the productive capabilities of crop, forest, and grazing land (e.g., upland areas, down-slope areas, and flat and bottom lands); sustaining productive forest areas and potentially commercial and non-commercial forest reserves; and maintaining the integrity of watershed for water supply and hydropower generation needs and water conservation zones; and the capability of aquifers to serve the needs of farm and other productive activities.
2. Actions to stop and reverse degradation—or at least to mitigate the adverse effects of earlier misuse—is increasingly important in uplands and watersheds, especially those where pressure from the resident populations are severe and where the destructive consequences of upland degradation are being felt in far more densely populated areas “downstream.”

Fortunately, in the past four decades, scientific advances and the application of improved knowledge and technologies by land managers and some farmers have resulted in significant total and per capita food increases, reduced food prices (figure 1), and the sparing of new land that otherwise would have been needed to achieve the same level of production (Evenson and Gollin 2003). For example, if yields of the six major crop groups that are cultivated on 80 percent of the total cultivated land area had remained at 1961 levels, an additional 1.4 billion hectares of farm land (more than double the amount of land currently being used) would have been required by 2004 to serve an expanding population. Asia alone would have required an additional 600 million hectares, which represents 25 percent more land area than is suitable for cultivation on that continent. Rather than enjoying surpluses of grains, Asia would now be heavily dependent on food imports if crop yields had remained at 1961 levels (Wood 2005). Nevertheless, the above gains have some medium to long-term costs (figure 1.1).

**Figure 1.1 Global Food Production, Food Prices, and Undernourishment in Developing Countries**



Source: Millennium Ecosystem Assessment Report, 2005.

Until recently, increases in agricultural productivity particularly in developed regions of the world (facilitated by both science and subsidy) have pushed world agricultural commodity prices down, making it increasingly difficult for marginal land farmers to operate profitably within existing technical and economic parameters. These trends may not be reliable pointers to the future.

In the 21st century, food and fiber production systems will need to meet three major requirements:

1. Adequately supply safe, nutritious, and sufficient food for the world's growing population.
2. Significantly reduce rural poverty by sustaining the farming-derived component of rural household incomes.
3. Reduce and reverse the degradation of natural resources and the ecosystem services essential to sustain healthy societies and land productivity.

#### *Drivers and Impacts of Global Change*

It is now known that the challenges to sustaining land productivity will need to be resolved in the face of significant but highly unpredictable changes in global climate—a key factor in natural and agro-ecosystem productivity. Other major issues that will influence how land use evolves to meet the challenge of food security include globalization of markets and trade, the increasing market orientation of agriculture, significant technological changes, and increasing public concern about the effects of unsustainable natural resource management.

Several decades of research have revealed the environmental impacts of land use throughout the globe, these impacts range from changes in atmospheric composition to the extensive modification of the earth's ecosystems. For example, land-use practices have played a role in changing the global carbon cycle and, possibly, the global climate: Since 1850, roughly 35percent of anthropogenic CO<sub>2</sub> emissions resulted directly from land use. Land-cover changes also affect regional climates through changes in surface energy and water balance (box 1.1).

### **Box 1.1 Historical Perspective on Landscapes, Land Management, and Land Degradation**

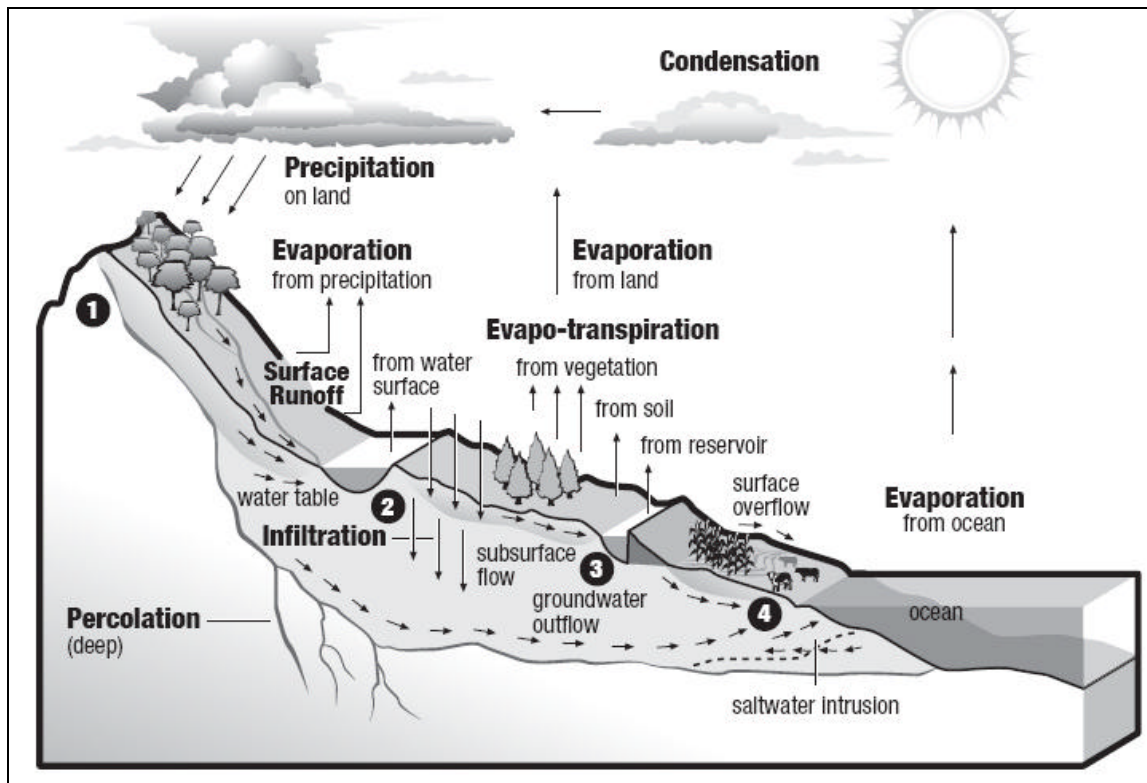
Concerns about soil and vegetation degradation and the impacts on land and water productivity are not new. Plato writing about Attica in the 4<sup>th</sup> century BC lamented:

“...there are remaining only the bones of the wasted body, as they may be called, as in the case of small islands, all the richer and softer parts of the soil having fallen away, and the mere skeleton of the land being left. But in the primitive state of the country, its mountains were high hills covered with soil, and the plains, as they are termed by us, of Phelleus were full of rich earth, and there was abundance of wood in the mountains. Of this last the traces still remain, for although some of the mountains now only afford sustenance to bees, not so very long ago there were still to be seen roofs of timber cut from trees growing there, which were of a size sufficient to cover the largest houses; and there were many other high trees, cultivated by man and bearing abundance of food for cattle. Moreover, the land reaped the benefit of the annual rainfall, not as now losing the water which flows off the bare earth into the sea, but, having an abundant supply in all places, and receiving it into herself and treasuring it up in the close clay soil, it let off into the hollows the streams which it absorbed from the heights, providing everywhere abundant fountains and rivers, of which there may still be observed sacred memorials in places where fountains once existed; and this proves the truth of what I am saying.”

*Source: DeFries, 2003. citing Plato, The Timaeus and Critias of Plato. Whitefish, MT: Kessinger Publishing.*

Humans have also transformed the hydrologic cycle to provide freshwater for irrigation, industry, and domestic consumption. Furthermore, anthropogenic nutrient inputs to the biosphere from fertilizers and atmospheric pollutants now exceed natural sources and have widespread effects on water quality and coastal and freshwater ecosystems. Land use has also caused declines in biodiversity through the loss, modification, and fragmentation of habitats; degradation of soil and water; and overexploitation of native species. Figure 1.2 below shows some of the watershed and landscape level interactions and potential consequences of individual land management decisions on water uptake and loss to the atmosphere (evapotranspiration) and hydrology.

**Figure 1.2 Typical Set of Production Activities (e.g., Forestry, Crop and Livestock Production, Hydropower, and Coastal Fisheries) Encountered in a Production Landscape**



*Note:* The land management interventions depicted at various points in the landscape all have an impact on surface and sub-surface water and nutrient flows and energy balances. Understanding how these inter-related but spatially separated interactions occur is very important for sustainable land management for enhanced productivity and ecosystem functions (World Bank, 2006).

Human activities now appropriate nearly one-third to one-half of global ecosystem production, and as development and population pressures continue to mount, so could the pressures on the biosphere. As a result, the scientific community is increasingly concerned about the condition of global ecosystems and ecosystem services.

Thus, land use presents us with a dilemma. On one hand, many land-use practices are absolutely essential for humanity, because they provide critical natural resources and ecosystem services, such as food, fiber, shelter, and freshwater. On the other hand, some forms of land use are degrading the ecosystems and services upon which we depend, so a natural question arises: Are land-use activities degrading the global environment in ways that may ultimately undermine ecosystem services, human welfare, and the long-term sustainability of human societies?

Here, we examine this question and focus on a subset of global ecosystem conditions we consider most affected by land use. We also consider the challenge of reducing the negative environmental impacts of land use while maintaining economic and social benefits.

#### *Food Production*

Together, croplands and pastures have become one of the largest terrestrial biomes on the planet, rivaling forest cover in extent and occupying ~40 percent of the land surface (See figure 1.3).

Changes in land-use practices have enabled world grain harvests to double in the past four decades, so they now exceed ~2 billion tons per year. Some of this increase can be attributed to a ~12 percent increase in world cropland area, but most of these production gains resulted from “Green Revolution” technologies, which include (a) high-yielding cultivars, (b) chemical fertilizers and pesticides, and (c) mechanization and irrigation. During the past 40 years, there has been a ~700 percent increase in global fertilizer use (and a ~70 percent increase in irrigated cropland area).

Although modern agriculture has been successful in increasing food production, it has also caused extensive environmental damage. For example, increasing fertilizer use has led to the degradation of water quality in many regions. In addition, some irrigated lands have become heavily “salinized,” causing the worldwide loss of ~1.5 million hectares of arable land per year, along with an estimated \$11 billion in lost production. Up to ~40 percent of global croplands may also be experiencing some degree of soil erosion, reduced fertility, or overgrazing.

The loss of native habitats also affects agricultural production by degrading the services of pollinators, especially bees. In short, modern agricultural land use practices may be trading short-term increases in food production for long-term losses in ecosystem services, which include many that are important to agriculture.

#### *Freshwater Resources*

Land use can disrupt the surface water balance and the partitioning of precipitation into evapotranspiration, runoff, and groundwater flow. Surface runoff and river discharge generally increase when natural vegetation (especially forest) is cleared. For instance, the Tocantins River Basin in Brazil showed a ~25 percent increase in river discharge between 1960 and 1995, coincident with expanding agriculture but no major change in precipitation.

Water demands associated with land-use practices, especially irrigation, directly affect freshwater supplies through water withdrawals and diversions. Global water withdrawals now total ~3900 km<sup>3</sup> yr.<sup>-1</sup> or ~10 percent of the total global renewable resource, and the consumptive use of water (not returned to the watershed) is estimated to be ~1800 to 2300 km<sup>3</sup> yr.<sup>-1</sup>

Agriculture alone accounts for ~75 percent of global consumptive use. As a result, many large rivers, especially in semiarid regions, have greatly reduced flows, and some routinely dry up. In addition, the extraction of groundwater reserves is almost universally unsustainable and has resulted in declining water tables in many regions.

Water quality is often degraded by land use. Intensive agriculture increases erosion and sediment load, and leaches nutrients and agricultural chemicals to groundwater, streams, and rivers. In fact, agriculture has become the largest source of excess nitrogen and phosphorus to waterways and coastal zones. Urbanization also substantially degrades water quality, especially where wastewater treatment is absent. The resulting degradation of inland and coastal waters impairs water supplies, causes oxygen depletion and fish kills, increases blooms of cyanobacteria (including toxic varieties), and contributes to waterborne disease.

#### *Forest Resources*

Land-use activities, primarily for agricultural expansion and timber extraction, have caused a net loss of ~7 to 11 million km<sup>2</sup> of forest in the past 300 years. Highly managed forests, such as timber plantations in North America and oil-palm plantations in Southeast Asia, have also replaced many natural forests; and now cover 1.9 million km<sup>2</sup> worldwide. Many land-use practices (e.g., fuel-wood collection, forest grazing, and road expansion) can degrade forest ecosystem conditions—in terms of productivity, biomass, stand structure, and species composition—even without changing forest area.

Land use can also degrade forest conditions indirectly by introducing pests and pathogens, changing fire-fuel loads, changing patterns and frequency of ignition sources, and changing local meteorological conditions.

#### *Regional Climate and Air Quality*

Land conversion can alter regional climates through its effects on net radiation, the division of energy into sensible and latent heat, and the partitioning of precipitation into soil water, evapotranspiration, and runoff. Modeling studies demonstrate that land-cover changes in the tropics affect climate largely through water-balance changes, but changes in temperate and boreal vegetation influence climate primarily through changes in the surface radiation balance. Large-scale clearing of tropical forests may create a warmer, drier climate, whereas clearing temperate and boreal forest is generally thought to cool the climate, primarily through increased albedo.

Urban “heat islands” are an extreme case of how land use modifies regional climate. The reduced vegetation cover, impervious surface area, and morphology of buildings in cityscapes combine to lower evaporative cooling, store heat, and warm the surface air. A recent analysis of climate records in the United States suggests that a major portion of the temperature increase during the last several decades resulted from urbanization and other land-use changes. Land cover change has also been implicated in changing the regional climate in China; recent analyses suggest that the daily diurnal temperature range has decreased as a result of urbanization.

Land-use practices also change air quality by altering emissions and changing the atmospheric conditions that affect reaction rates, transport, and deposition. For example, tropospheric ozone (O<sub>3</sub>) is particularly sensitive to changes in vegetation cover and biogenic emissions. Land-use practices often determine dust sources, biomass burning, vehicle emission patterns, and other air pollution sources. Furthermore, the effects of land use on local meteorological conditions, primarily in urban heat islands, also affect air quality: Higher urban temperatures generally cause O<sub>3</sub> to increase.

#### *Infectious Diseases*

Habitat modification, road and dam construction, irrigation, increased proximity of people and livestock, and the concentration or expansion of urban environments all modify the transmission of infectious disease and can lead to outbreaks and emergence episodes. For example, increasing tropical deforestation coincides with an upsurge of malaria and its vectors in Africa, Asia, and Latin America, even after accounting for the effects of changing population density.

Disturbing wildlife habitat is also of particular concern, because ~75 percent of human diseases have links to wildlife or domestic animals. Land use has been associated with the emergence of bat-borne Nipah virus in Malaysia, cryptosporidiosis in Europe and North America, and a range of food borne illnesses globally. In addition, road building in the tropics is linked to increased bushmeat hunting, which may have played a key role in the emergence of human immunodeficiency virus types 1 and 2; simian foamy virus was recently documented in hunters, confirming this mechanism of cross-species transfer.

The combined effects of land use and extreme climatic events can also have serious impacts, both on direct health outcomes (e.g., heat mortality, injury, fatalities) and on ecologically mediated diseases. For example, Hurricane Mitch, which hit Central America in 1998, exhibited these combined effects: 9,600 people perished, widespread water- and vector-borne diseases ensued, and one million people were left homeless. Areas with extensive deforestation and settlements on degraded hillsides or floodplains suffered the greatest morbidity and mortality.

*Production Landscapes: The Context for Land Management*

When one travels on an airplane, the view from the window reveals landscapes below with mountain ranges, forests, grasslands, coastlines, and sometimes deserts. As human civilization evolved, people planted crops, reared animals, developed complex irrigation schemes, built cities, and devised technologies to make life more comfortable and less vulnerable to droughts, floods, and other potentially damaging climatic events. The outcomes of this human occupation are transformed landscapes over 40 percent of the Earth's ice-free land surface. Only places that are extremely cold, hot, very mountainous, or as yet inaccessible remain free from human use (See figure 1.3).

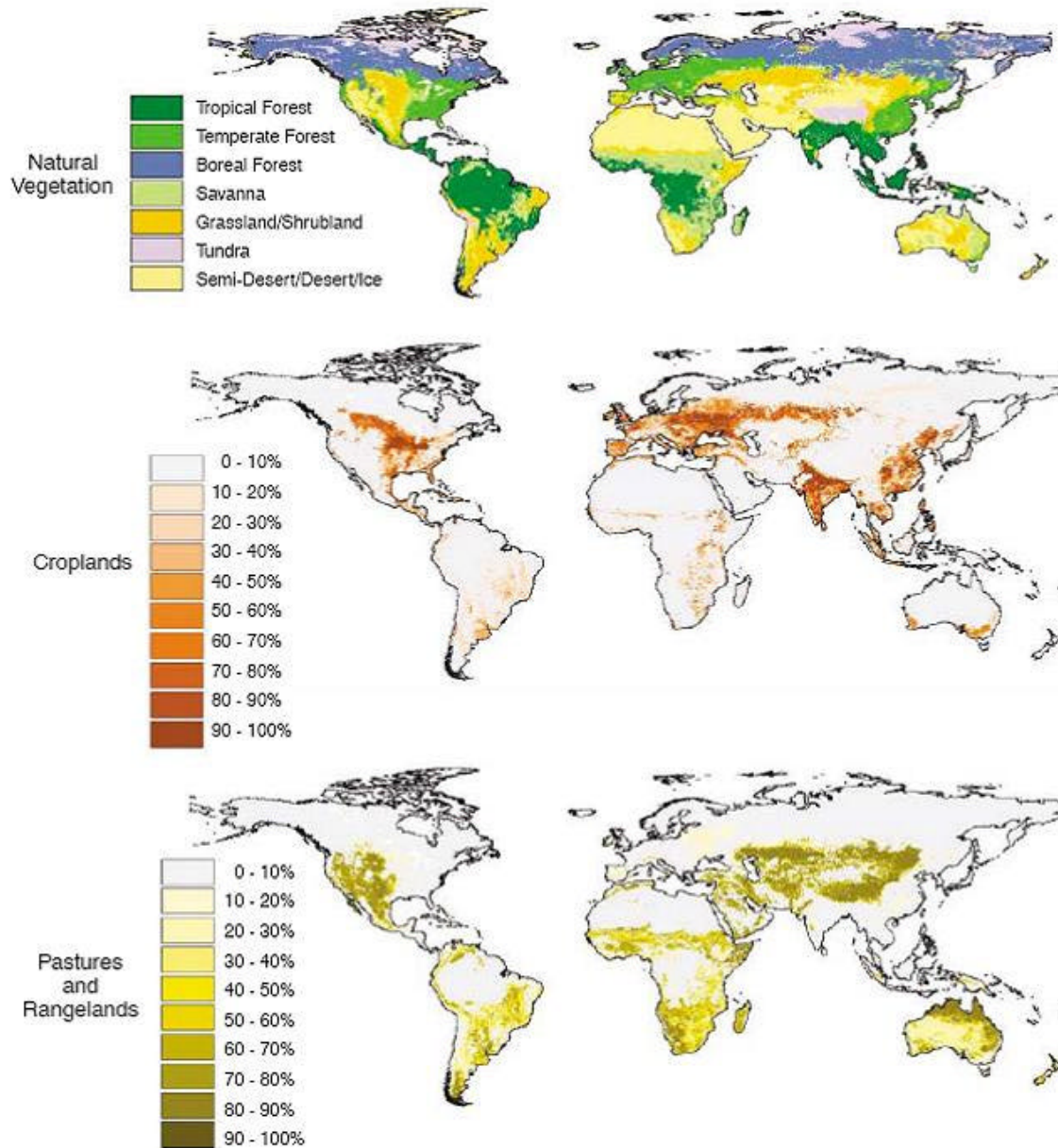
Landscapes also reveal how people obtain their food and pursue their livelihoods. In the industrialized world of North America and Western Europe, a majority of people live in urban areas (77 percent in 2003) and obtain food transported from land devoted to high-yield agriculture. Diets are relatively high in animal products. Agricultural production is highly mechanized, with only 15 percent of people living in rural areas engaged in farming or ranching. This pattern is markedly different in parts of the world that are still in agrarian stages of development (figure 1.4).

Although overall global food production has increased 168 percent over approximately the past 40 years and is ample to feed all 6.5 billion people on the planet today, 13 percent of the world's population still suffered from malnutrition between 2000 and 2002 because they were too poor to purchase adequate food. The imprint of this paradox is seen throughout the rural landscape of the developing world in crops grown on infertile soils and steep slopes, mosaics of shifting cultivation, forests scavenged for fuelwood, and seasonal migrations pursuing fodder for livestock. Most people in the developing world live in rural areas, with South Asia having the highest percentage at more than 70 percent (Latin America and the Caribbean is the most urbanized developing region.) Of the rural population throughout all developing regions, the vast majority is engaged in agriculture, growing low-yield crops for their own households and local markets. Diets also contrast with those in the industrialized world, with consumption of animal products far less than half and per capita caloric intake at 65 to 80 percent of that in industrialized societies.

Poverty, agriculture, and land use make a complex and challenging system with many flaws and interacting elements. Poor farmers do not want to be poor – and few choose actively to damage their environments. The reason so many are living on the 'edge of survival' is that too many of their traditional approaches to agricultural production are breaking down. Economic growth has been insufficient to offer alternative means of employment for the rural poor. Profits from farming at low levels of productivity have been too small to allow farmers to reinvest in their farms and maintain productivity at acceptable levels (Eicher, 1990; Blackie, 1994). Meanwhile, continual increases in population have depleted both the available resource base and social entitlements which hitherto provided a state of equilibrium in rural areas of Africa (Lele, 1989).

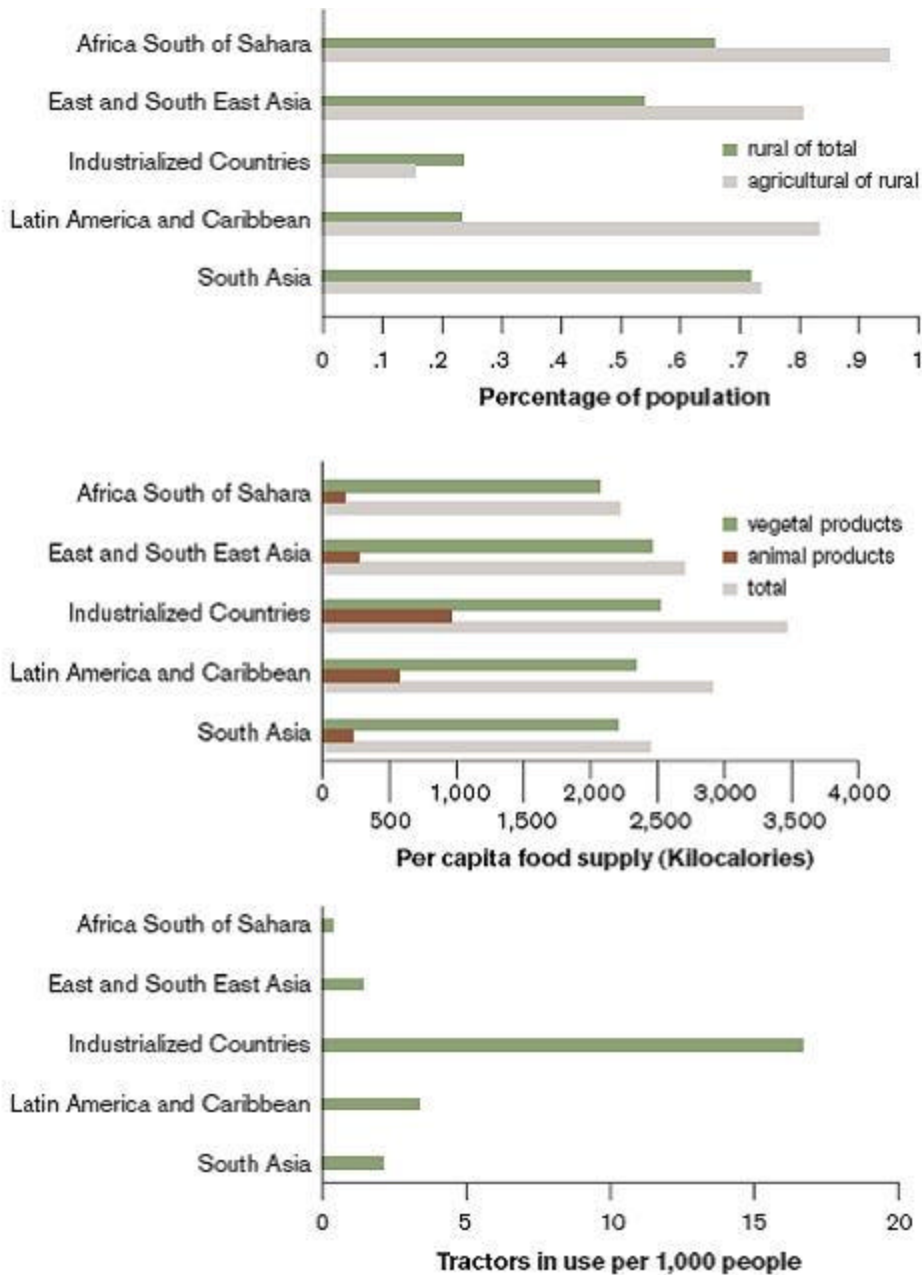


**Figure 1.3 Geographical Distributions of Cropland and Pasture in the 1990s**



Note: The “potential vegetation” that would exist in the absence of human land use is estimated based on climate (top).  
 Source: Adapted from: J. Foley et al. 2005. “Global Consequences of Land Use,” *Science*, 22: 570–74.

**Figure 1.4 Food Production/Consumption World Comparisons, 2003**



Note: Top: Percentage of total population living in rural areas is highest in South Asia and lowest in industrialized countries, while agricultural populations (agricultural population is defined as all persons depending for their livelihood on agriculture, hunting, fishing, or forestry) comprise more than 70 percent of the rural population in all developing regions, but only 15 percent in industrialized countries; Middle: Per capita food supply per day and proportion of total in animal products is highest in industrialized countries; Bottom: Food production is more mechanized in industrial countries, as illustrated by the number of tractors in use.

Source: Food and Agriculture Organization of the United Nations Statistical Databases (FAOSTAT), <http://www.faostat.fao.org>.

Those most in need of new livelihood options are the least able to pay for them. Furthermore, the advice they receive on the choices open to them is disgraceful – what the farmer needs is reliability and consistency of performance. A single mother, hoping to harvest a tonne of rice on a hectare of depleted upland soil, can ill afford to lose 100 kg of her harvest to a crop pest or disease in a single season even if, under some conditions (which she may not be able to achieve), she can potentially get a higher yield from a new variety. She needs to move to a higher level of productivity but cannot afford the means to lift herself there. While group savings and credit schemes (such as Savings and Credit Cooperative Societies, Household Income Security Associations, Self-Help Groups) can help poor families to access inputs to get out of the poverty spiral, the effectiveness of such interventions is badly blunted when the inputs themselves are poorly tailored to the needs of the poor. SLM practices are often complex, difficult to implement, and with payoffs which may be beyond the horizon of the poor. But, as the cases in this source book will show, these constraints do not mean that they are impractical or impossible for the poor to adopt.

Much of the debate on poverty revolves around the low prices that farmers get for their produce. Remember first that the priority for the rural poor is to grow their own food. Many of the rural poor do not even produce to feed themselves all year round – so they buy food when supplies are short and prices high. Poor people do not need expensive food. Thus an evident priority in the struggle against poverty is to bring food prices down. The costs of many of the improved technologies (seeds, fertiliser, improved livestock breeds) needed by smallholders, despite the ongoing efforts at market development, will remain high. Low cash cost technologies (home produced seed, household composts) often have a substantial cost in terms of labour – which is also a scarce resource in many poor households.

The advice given to many poor farmers for the use of essential inputs, (both those purchased from outside and those which the farmer may generate from homestead resources – such as manures and home-saved seed), actually serves actively to discourage their use. In large part this is because of inadequate incorporation of basic economic parameters into farmer recommendations (Blackie, 2005). The information provided frequently overlooks the obvious fact that an expensive input (whether in cash or labour terms) can be profitable if it is used efficiently. The knowledge the poor seek is how to make best use of the limited amounts that they are able to purchase. So poverty alleviation and food security have to be arranged around low food prices and efficient production methods. With low food prices, the poor can use their limited cash to invest in better housing, education and health care. With high food prices, they are further trapped in poverty, and the opportunities for livelihood diversification are few.

The human imprint on the landscape emerges from millions of individual decisions in pursuit of food and livelihoods. Through time, as societies evolve from agrarian to industrial and information-based economies, the landscape mirrors accompanying shifts in how people obtain food, what they eat, and where they work. Historical examples in North America and Europe follow a general pattern, and similar patterns are emerging in some developing regions, but with one major caveat – the early stages of agricultural transformation and industrialization on Europe and North America were supported by significant shifts of populations to new lands – through colonization and settlement. In today's crowded world, that “safety” valve is no longer an option.

Instead a “Green Evolution” strategy is needed to help people transform their own landscapes rather than seeking to escape to fresh pastures. Local knowledge (of soils, landscapes, markets, and climate) is linked to the best of national and international expertise in a focused, problem solving effort. The focus is on quality and impact, facilitated through enhanced networking and coordination among the various sector stakeholders and international organisations. The best options are pulled

together and then promoted through large-scale initiatives. The poor influence the choice of recommendations, while the private sector contributes towards sector needs such as seed and market systems. In this way, the power of the millions of individuals' decisions can be tapped to create a more benign and sustainable human footprint on the landscape. The "Green Evolution strategy encourages the efficient and swift transformation of practices leading to sustainable land management through harnessing the best of skills in a collaborative, 'learning by doing' manner in which all feel ownership and pride. Existing structures are improved and enhanced to build change through an evolutionary, rather than a revolutionary, approach. This is cost-effective, brings the best of developing country and international expertise together in a problem solving format, and can be rapidly scaled up to reach the poor quickly and effectively.

This process of participatory experimentation empowers the poor through knowledge generation and sharing. Through experimentation, the poor can investigate, and contribute to, the development of practical, affordable, and sustainable practices which are reliable and robust under their circumstances. The poor gain the information they need to select the best technology combinations for their conditions. They then share this knowledge with their fellow farmers using different channels such as farmer field schools or field tours, and field days. Information from pilot project areas spreads widely and quickly across geographical and socio-economic gradients. Experimentation is followed by diversification. After experimenting with different crops, farmers choose which crops respond favourably to inputs or those performing well in their environments. They adopt an incremental adoption strategy. As their knowledge increases on a specific technology, and farm produce increases and more profits accrue from the sales, farmers gradually expand their capacity to diversify into other production activities.

The key element is building the trust and respect of the poor - requiring a continuing exercise of discussing and coming to a consensus on options, together with obtaining routine and informed feedback on results. Some of the tools are already in use. Researchers, in particular, have been highly innovative in developing the necessary tools to meet the challenge of conducting participatory activities with many clients over an extended geographical area in a cost- and time-effective manner. See, for example, Snapp's 'mother and baby' trial design (Snapp et al., 2003) which collects quantitative data from mother trials managed by researchers, and systematically cross-checks them with baby trials that are managed by farmers. This quickly generates 'best bet' options that are "owned" by the participating communities as well as creating a fertile environment for developing new insights and priorities (Snapp et al., 2003). The eventual product has several advantages:

- It is owned by those who need to adopt it so they have a genuine belief that this actually is useful
- It builds bridges of communication between target communities and the agencies working to assist them (the chronic research/extension linkage problem that so many words have been wasted on), and,
- It creates a confidence amongst the target population that they can solve their own problems – leading to quicker innovation and also spread of innovation across communities.

In many of the success stories developed in the subsequent investment notes, the path has been laid through skilful building of partnerships with farmers, communities, and institutions in the countryside.

### *Land Management Trade-offs*

Land use change has allowed civilizations to grow crops, feed livestock, obtain energy, build cities, and carry out myriad other activities that underlie material advancement of any society and progression through the other major societal transitions. Land use change also profoundly alters ecosystems as vegetation is cleared and biomass is diverted for human consumption. Unintended environmental consequences potentially undermine future land use options.

Since the publication of the Brundtland report, the concept of sustainability has received increasing attention in agriculture, yet researchers have struggled to “operationalize” the concept. Smyth and Dumanski (1993) sub-divided the general concept of sustainability into four main pillars: (a) representing productivity, (b) stability of production, (c) soil and water quality, and (d) socioeconomic feasibility. A slightly different approach for using the concept of sustainability has been to define various indicators (e.g., Bockstaller et al. 1997; Pieri et al. 1995).

Several practical problems arise in implementing this strategy, including the large amount of data needed to quantify a large number of different sustainability indicators, and the challenge of understanding the complex interactions among such indicators. Some researchers have combined indicators into indexes (e.g., Farrow and Winograd, 2001; Sands and Podmore, 2000). This procedure raises the question of how indexes measured in different units can be meaningfully aggregated. The choice of “weights” used for such aggregation is often arbitrary and lacks adequate rigor. One well-known strategy for weighting different indexes has been developed by economists for benefit-cost analysis, wherein systematic methods have been developed to ascertain monetary values to attribute to both market and non-market goods and services, including the services of natural capital. Yet even these systematic attempts to value and aggregate market and non-market goods have proved controversial and have not been widely accepted within and outside the economics profession (Belzer, 1999; Portney, 1994).

The alternative approach taken in tradeoff analysis is to work with decision makers to identify a limited set of high-priority indicators, and then provide decision makers with quantitative estimates of the relationships among those indicators; leaving to the decision makers the task of subjectively assessing the implied tradeoffs or win-win options. Tradeoff curves are used to communicate information about tradeoffs to decision makers. Tradeoff curves are designed to embody the principle of opportunity cost in production systems. They are typically constructed by varying parameters in the production system that affect the economic incentives perceived by farmers in their land use and input use decisions.

A key potential benefit of the tradeoff approach is the ability to model the desirability and likely effects of scaling up good practice. Most often the scaling up approach that is used is based on the simplistic assumption of additive economic and ecological benefits as one scales up good practice. The goal of tradeoff analysis is to support decision making related to public policy issues associated with agricultural production systems. Thus, the focus of tradeoff analysis is to provide information at a spatial scale relevant to such policy questions – typically a unit of analysis such as a watershed, a political unit, a region, or even at the national level. Yet, the environmental impacts of production systems are generally site-specific. A critical question, therefore, is how to bridge the gap from the site-specific impacts of agricultural production systems to the scale relevant for policy decisions. The Tradeoff Analysis Model is designed to solve this problem by characterizing the population of bio-physical and economic decision making units in a region, simulating their behavior at the field scale, and then aggregating outcomes to a regional scale relevant for policy analysis using tradeoff curves and other means of communicating results.

### *Confronting the Effects of Land Use*

Current trends in land use allow humans to appropriate an ever-larger fraction of the biosphere's goods and services while simultaneously diminishing the capacity of global ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality, and mediate infectious diseases. This assertion is supported across a broad range of environmental conditions worldwide, although some (e.g., alpine and marine areas) were not considered here. Nevertheless, the conclusion is clear: Modern land use practices, while increasing the short-term supplies of material goods, may undermine many ecosystem services in the long-run, even on regional and global scales.

Confronting the global environmental challenges of land use will require assessing and managing inherent trade-offs between meeting immediate human needs and maintaining the capacity of ecosystems to provide goods and services in the future. Assessments of trade-offs must recognize that land use provides crucial social and economic benefits, even while leading to possible long term declines in human welfare through altered ecosystem functioning .

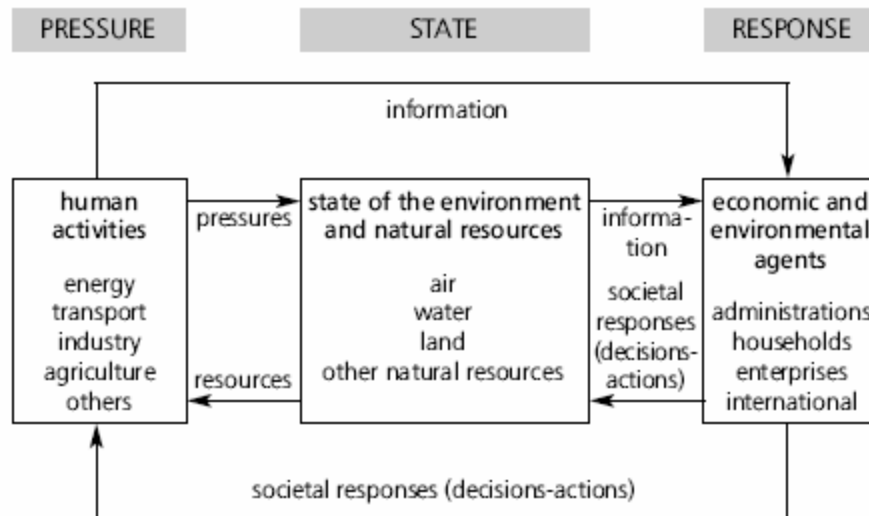
### *Selecting and Using Appropriate Indicators for Sustainable Land Management and Landscape Resilience*

Sustainable land-use policies must also assess and enhance the resilience of different land-use practices. Managed ecosystems, and the services they provide, are often vulnerable to diseases, climatic extremes, invasive species, toxic releases, and the like. Increasing the resilience of managed landscapes requires practices that are more robust to disturbance and can recover from unanticipated "surprises." There is an increasing need for decision-making and policy actions across multiple geographic scales and multiple ecological dimensions. The very nature of the issue requires it: Land use occurs in local places, with real-world social and economic benefits, while potentially causing ecological degradation across local, regional, and global scales. Society faces the challenge of reliably assessing impacts and developing strategies that reduce the negative environmental impacts of land use across multiple services and scales while sustaining social and economic benefits.

Indicators are inter-linked components and processes in one land management system, not a group of separate variables. Although each single indicator could be interpreted independently, SLM as an entity can only be assessed if its indicators show a meaningful linkage. In the context of SLM, different biophysical and socioeconomic indicators, of both a quantitative and a qualitative nature are selected, measured, and evaluated. This heterogeneous mix of indicators requires a qualitative frame or structural model for a meaningful analysis of the linkages and causal effects of the indicators (box 1.2).

## Box 1.2 Pressure-State-Response Framework

The following example presents the Pressure-State-Response framework. It can be used as a structural model for identifying core issues, formulating impact hypotheses, and selecting a meaningful set of indicators. The indicators are related to the components of the model.



### Indicator selection following the PSR Framework

The Sahara and Sahel Observatory identified the following topics for coverage when developing impact indicators, using the Pressure-State-Response Framework:

#### Driving Forces causing pressure on natural resources

- population pressure, economic growth, urbanisation
- policy failures/distortions (stagnant technology, delayed intensification)
- imperfect markets (lack of markets, poor market access)
- transaction costs and imperfect information (limited access to information about market opportunities)
- social inequity, poverty
- political and social instability

#### Pressure indicators

- changes in cropping techniques
- financial position of holdings
- fuelwood/charcoal consumption
- use of crop residues
- use of animal dung for fuel
- price of fuelwood/charcoal
- ...

#### State indicators

- rate of deforestation
- rate of soil erosion
- degree of salinisation
- soil crusting and compaction
- crop productivity
- livestock productivity
- nutrient balance (on-farm organic matter recycling)
- ...

#### Response indicators

- change of legislation
- investments
- tree planting
- state conservation programmes
- farmer conservation groups
- farmer adoption of tree planting and soil and water conservation

Source: Sustainable Land Management Tool Kit, University of Berne.

## **SECTION II: Diversity of Land Management Systems and Poverty Alleviation**

To focus on and structure the SLM sourcebook we used the comprehensive 2001 FAO-World Bank study “Farming Systems and Poverty: Improving Farmers’ Livelihoods in a changing World (Dixon et al., 2001). The study adopted a farming systems approach to provide an agricultural perspective to the revision of the Bank’s Rural Development Strategy. It drew on many years of experience in FAO and the World Bank, as well as in a number of other national and international institutions. More than 70 major farming systems were defined throughout the six developing regions of the world. Findings were supported by more than 20 case studies from around the world which analyzed innovative approaches to small farm or pastoral development. Although recognizing the heterogeneity that inevitably exists within such broad systems, the farming systems approach provides a framework for understanding the needs of those living within a system, the likely challenges and opportunities that they will face over the next 30 years, and the relative importance of different strategies for escaping from poverty and hunger.

The key farming system types identified and described by Dixon et al., (2001) are briefly summarized here to guide and focus the interventions and investment examples and guidelines.

### *Overview of farming systems as a baseline for targeting investments*

A farming system is defined as a *population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate*. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households.

The delineation of the major farming systems provides a useful framework within which appropriate agricultural development strategies and interventions can be determined. The classification of the farming systems of developing regions has been based on the following criteria:

- *Available natural resource base*. This includes water, land, grazing areas and forest; climate, of which altitude is one important determinant; landscape, including slope; farm size, tenure and organization.
- *Dominant pattern of farm activities and household livelihoods*. This includes field crops, livestock, trees, aquaculture, hunting and gathering, processing and off-farm activities; and taking into account the main technologies used, which determine the intensity of production and integration of crops, livestock, and other activities.

Based on these criteria, eight broad categories of farming system have been distinguished and 72 farming systems identified:

1. Irrigated farming systems (3), embracing a broad range of food and cash crop production;
2. Wetland rice based farming systems (3) dependent upon monsoon rains supplemented by irrigation
3. Rainfed farming systems in humid (and subhumid) areas (11) of high resource potential, characterized by a crop activity (notably root crops, cereals, industrial tree crops – both small scale and plantation – and commercial horticulture) or mixed crop-livestock systems;
4. Rainfed farming systems in steep and highland areas (10) which are often mixed crop-livestock systems;



5. Rainfed farming systems in dry or cold areas (19) with mixed crop-livestock and pastoral systems merging into sparse and often dispersed systems with very low current productivity or potential because of extreme aridity or cold;
6. Dualistic farming systems with both large-scale commercial and smallholder farms (16) across a variety of ecologies and with diverse production patterns;
7. Coastal artisanal fishing mixed farming systems (4) often mixed farming systems
8. Urban based farming systems (6) typically focused on horticultural and livestock production.

The eight categories of farming system are further compared in Table 2.1, showing the areas of total land, cultivated land and irrigated land, agricultural population, and market surplus. A recent study investigating alternative household strategies for land management (farming) systems in developing countries reinforced the need for greater development attention to diversification and intensification (box 2.1). In the relatively constrained circumstances of rain-fed highlands and rain-fed dry/cold climates, however, off-farm employment and exit from agriculture are important (though not always easily achievable).

### **Box 2.1 Household Strategies to Improve Livelihoods**

- Intensification of existing farm production patterns through increased use of inputs or better quality inputs.
- Diversification of production, with emphasis on greater market orientation and value addition involving a shift to new, generally higher-value products.
- Increase farm size, an option limited to a few areas where additional land resources are still available.
- Increase off-farm income to supplement farm activities and provide financing for additional input use.
- Exit from agriculture, including migration from rural areas.

*Source: Dixon et al. 2001*

#### *Principles for Sustainable Land Management in Rain-fed Farming Systems*

For all the above rainfed systems, the following principles have been identified in a number of studies which includes (Dixon et al. 2001).

Good land management requires an *integrated and synergistic resource management approach* that embraces locally-appropriate combinations of the following technical options:

- Build-up of soil organic matter and related biological activity to optimum sustainable levels for improved moisture, infiltration and storage, nutrient supply, and soil structure through the use of compost, farmyard manure, green manures, surface mulch, enriched fallows, agroforestry, cover crops, and crop residue management;
- Integrated plant nutrition management with locally appropriate and cost-effective combinations of organic/inorganic and on/off-farm sources of plant nutrients (e.g., organic manures, crop residues, rhizobial N-fixation, transfer of nutrients released by weathering in the deeper soil layers to the surface by way of tree roots and leaf litter, use of rock phosphate, lime, and mineral fertilizer);

- Better crop management using improved seeds of appropriate varieties, improved crop establishment at the beginning of the rains (to increase protective ground cover, thereby reducing water loss and soil erosion), effective weed control, and integrated pest management;
- Better rainwater management to increase infiltration and eliminate or reduce runoff so as to improve soil moisture conditions within the rooting zone, thereby lessening the risk of moisture stress during dry spells, while reducing erosion;
- Improvement of soil rooting depth and permeability through breaking of cultivation induced compacted soil layers (hoe/plough pan) through conservation tillage practices by means of tractor drawn sub-soilers, ox drawn chisel ploughs, or hand hoe planting pits/double dug beds, or inter-planting of deep rooted perennial crops/trees and shrubs); and
- Reclamation, where appropriate (i.e., if technically feasible and cost-effective), of cultivated land that has been severely degraded by such processes as gullying, loss of topsoil from sheet erosion, soil compaction, acidification, or salinization.

The above list of good SLM principles is used to derive the suggested lending directions below and also as a basis for the Investment Notes and Innovative Action Profiles presented for potential application in areas with rain-fed farming systems.

#### *Future Directions for Investments*

Public and private investments to intensify sustainable production systems are generally best focused on (a) facilitating the capacity of farmers, government, and the private sector to make decisions about the appropriate technological and resource allocation; and (b) providing the necessary social/organizational and physical infrastructure. It is critical that agricultural production systems be sufficiently flexible to adapt to changing environmental and economic conditions.

New technologies will be developed, and variations on established production systems are likely to continue. At present, options that may warrant public sector support include:

- *Variety improvement* will remain crucial as it becomes increasingly difficult to “adjust the environment to the plant.” Plant varieties adapted to specific production environments and sustainable agricultural practices, and to resisting specific pests and diseases, will become increasingly important. Livestock improvement will increase productivity and make more efficient use of scarce land and water. Biotechnology’s potential as a tool for sustainable production systems should be evaluated and supported on a case-by-case basis.
- *Conservation farming* practices can reduce unnecessary input use. Minimum tillage or no-till crop production reduces labor and equipment costs, enhances soil fertility, reduces erosion, and improves water infiltration, thereby reducing unit costs and conserving land resources. Improved crop residue management, including mulching, is often a necessary component of these systems. No-till systems of conservation farming have proven a major success in Latin America and are being used in South Asia and Africa.
- *Organic farming* eliminates use of chemical inputs and can be sustainable as long as practices maintain productivity at a reasonable level, consistent with price incentives provided by growing market opportunities for organic produce. Organic farming depends mainly on the development of niche markets with reliable standards and certification systems for production.

- *IPM systems* have been developed for many crops to control pests, weeds, and diseases while reducing potential environmental damage from excessive use of chemicals. Scaling up IPM technologies is a challenge, as these management systems rely on farmers' understanding of complex pest ecologies and crop-pest relationships. Thus, although IPM messages need to be simplified, IPM systems require continuous research and technical support and intensive farmer education and training along with policy-level support.
- *Precision agriculture* improves productivity by better matching management practices to localized crop and soil conditions. Relatively sophisticated technologies are used to vary input applications and production practices, according to seasonal conditions, soil and land characteristics, and production potential. However, with help from extension and other services, resource-poor farmers can also apply principles of precision agriculture for differential input application and management on dispersed small plots. Appropriate technologies suitable for use by small-scale farmers include simple color charts to guide decisions on fertilizer application, and laser leveling of fields for irrigation.
- *Fertilizer use is relatively low especially in Africa* and soil fertility is declining, which explains much of the lagging agricultural productivity growth in Africa relative to other regions. Fertilizer use is resurfacing on the African development agenda, and policy makers face a major challenge in deciding how to promote increased use of mineral fertilizers. There are several obstacles to overcome to avoid fertilizer-market failure, however. They include strong seasonality in demand for fertilizer, the riskiness of using fertilizer (i.e., stemming from weather-related production variability and uncertain crop prices), highly dispersed demand for fertilizer, a lack of purchasing power on the part of many potential users, the bulkiness and perishability of most fertilizer products, and the need to achieve large volumes of throughput in fertilizer procurement and distribution to capture economies of scale.

Agricultural intensification is a key and desirable pathway to increase in the productivity of existing land and water resources in the production of food and cash crops, livestock, forestry, and aquaculture. Generally associated with increased use of external inputs, intensification is now defined as the more efficient use of production inputs. Increased productivity comes from the use of improved varieties and breeds, more efficient use of labor, and better farm management (Dixon et al. 2001). Although intensification of production systems is an important goal, these land management systems need to be sustainable to provide for current needs without compromising the ability of future generations to meet their needs.

Some of the *system adaptations* that are options for sustainable intensification of production include:

- *Integrated crop-livestock production* can enhance environmental sustainability by feeding crop residues to animals, thus improving nutrient cycling. This crop-livestock approach is likely to become increasingly profitable given the large, worldwide increase in demand for meat, milk, and other products derived from animals. The suitability of many livestock enterprises to small-farm production systems holds considerable potential for poverty reduction.
- *Agricultural diversification* must be pursued where existing farming systems are not environmentally sustainable or economically viable. Diversification into high-value, nontraditional crops and livestock systems (e.g., horticultural crops) are attractive because of the growing market demand for these products, their high labor intensity, and the high returns to labor and management. In contrast to other low-input strategies for sustainable

intensification, diversification to high-value products frequently requires the use of relatively high levels of inputs, which must be monitored and managed carefully.

- *Tree crops*, including fruit, beverage, timber, and specialty crops, offer opportunities for environmentally sound production systems, because they maintain vegetative cover and can reduce soil erosion. Tree crops, especially multiple-species plantations, help maintain a relatively high level of biodiversity. They are important for export earnings in many countries and, although often suited to large-scale plantations, are also important to smallholders with mixed cropping systems.

Both public and private investments are needed to support the transition to more profitable and sustainable farming systems. Sustainable intensification will frequently require activities that provide an enabling environment and support services for the market-led changes, or component technologies, including management practices. Much investment will come from market supply chains based in the private sector, including input supply and output marketing and processing enterprises and farmers. Public investment will need to focus on (a) new knowledge and information services, (b) public policy and regulatory systems, and (c) market and private sector development.

*New knowledge and information services.* A key investment area is in technology associated with management innovations to improve overall productivity and sustainability of agricultural systems. Much research will focus on developing improved management systems, with an emphasis on understanding agricultural ecology, farm management, and social systems. Biotechnology offers opportunities to diversify and intensify agricultural production systems—tissue culture for production of virus-free planting stock (e.g., bananas) and transgenic crops with pest resistance or other beneficial characteristics.

Because of the larger spatial and temporal scales of operations and likely impacts in landscape and watershed investments relative to a single site or community project, it is important to be aware of the difficulties to be overcome. For example, the successful scaling up site-specific SLM innovations also invariably requires negotiated implementation arrangements suited to local power structures and institutions. Safeguard policies are often critical to SLM and natural resource management investments and the key Bank policies are identified below for users of this source book (box 2.2).

## Box 2.2 Key Safeguard Policy Issues for Sustainable Land Management and Natural Resource Management Investments

- *Environmental Assessment (Operational Policy [OP]/Bank Procedure [BP] 4.01)*. An environmental assessment is required if a natural resource management (NRM) project has potential for adverse environmental risks or impacts.
- *Natural Habitats (OP 4.04)*. Protection of natural habitats (land and water areas where most of the original plant and animal species are still present) is required for any NRM investment that may cause degradation of the habitat.
- *Projects in International Waterways (OP 7.50)*. The borrower must notify other riparian countries of any proposed NRM investment involving a body of water that flows through or forms part of the boundary of two or more countries.
- *Involuntary Resettlement (OP/BP 4.12)*. A Resettlement Action Plan is required if an NRM investment results in physical relocation, loss of land or access to land or other assets, or impacts on livelihoods arising from restrictions on access to parks or protected areas.
- *Indigenous Peoples (Operational Directive 4.20)*. An Indigenous Peoples Action Plan is required if an NRM investment affects indigenous people.
- *Forestry (OP 4.36)*. Government commitment to undertake sustainable management and conservation-oriented forestry is required for any investment with potential to impact significantly on forested areas. (Investment with exclusive focus on environmental protection or supportive of small-scale farmers may be appraised on its own merits.)

Source: World Bank, Operational Manual.

**Table 2.1 Comparison of Farming Systems by Category**

Category characteristic	Irrigated systems	Wetland rice-based	Rainfed humid	Rainfed highland	Rainfed dry/cold	Dualistic (large/small)	Coastal artisanal fishing	Urban-based
Number of systems	3	3	11	10	19	16	4	6
Total land (m ha)	219	330	2013	842	3478	3116	70	n/a
Cultivated area (m ha)	15	155	160	150	231	414	11	n/a
Cultivated/Total (%)	7	47	8	18	7	13	16	n/a
Irrigated area (m ha)	15	90	17	30	41	36	2	n/a
Irrigated/ Cultivated (%)	99	58	11	20	18	9	19	n/a
Agric. population (million)	30	860	400	520	490	190	60	40
Agric. Persons/Cult (p/ha)	2.1	5.5	2.5	3.5	2.1	0.4	5.5	n/a
Market surplus	High	medium	medium	low	low	medium	high	high

Note. "Cultivated area" refers to both annual and perennial crops. n/a = not available

Source: FAO data and expert knowledge.

## **SECTION III: Major Farming Systems: Investment Options and Innovations**

### *Overview*

For this edition of the sourcebook, we selected the three major rain-fed systems out of the eight system types identified by Dixon et al. (2001) for development of detailed investment notes for this edition of the SLM sourcebook. The decision to start with three rain-fed systems was based on the level of available resources (funds and time) and also on the fact that these rain-fed systems occupy over 540 million hectares of cultivated land globally and involve ~ 1.4 billion people, who in turn practice ~40 different land management and cropping arrangements.<sup>1</sup>

We intend to systematically cover the remaining farming systems in future editions of the SLM source book. The three system types selected for this edition of the SLM Sourcebook are: (a) rain-fed farming systems in humid (and sub-humid) areas; (b) rain-fed farming systems in highland and sloping areas; and (c) rain-fed farming systems in dry (semi-arid and arid) areas.

For each farming system type, good practice examples are identified and summarized as follows:

*Investment Notes* (INs) summarize good practice and lessons learned in specific investment areas, to provide a brief, but technically sound, overview for the non-specialist. For each IN the investments have been evaluated in different settings for effectiveness and sustainability, and can be broadly endorsed by the community of practitioners from within and outside the Bank.

*Innovative Activity Profiles* (IAPs) highlight design of successful or innovative investments. These provide a short description of an activity in the Bank's portfolio or that of a partner agency, focusing on potential effectiveness in poverty reduction, empowerment, or sustainability. Activities profiled have often not been sufficiently tested and evaluated in a range of settings to be considered "good practice," but should be closely monitored for potential scaling up.

### **Section III-A. Rainfed Humid Farming and Land Management Systems**

#### *Overview*

These systems are found in the humid and sub-humid zones of Africa, Asia, and Latin America and support an agricultural population of approximately 400 million on ~160 million ha of cultivated land, of which only 11 percent are irrigated. Pressure on land is typically moderate -- only 2.5 persons per cultivated ha on average -- although there are some areas of intense pressure.

They depend on slash and burn agriculture where forest is cleared in order to cultivate root crops, cereals, and groundnuts among others. The number of cattle and small ruminants are low. Cash income is rather based on forest products and wild game than on cash crops. These systems are characterized by their physical isolation, with a lack of roads and markets hindering their economic development. Deforestation and loss of biodiversity is a serious issue with impact from local to global level. Because of locally increasing population pressure, fallow periods are shortened resulting in soil fertility loss and yield decline, which can drive further deforestation. The agricultural growth potential is moderate. Despite an existence of large uncultivated areas and the high rainfall, yield increases in the near future are expected to be modest. The fragility of the soils and the call for rainforest protection, with its associated biodiversity and multiple environmental services, represent strong arguments against a further extension of the agricultural system.

The remaining eight systems can be characterized as *mixed farming systems* in the humid and sub-humid agro-ecological zones. Cereals, root crops, and tree crops are cultivated for food and cash. There is little irrigation. These systems often have an important livestock component. The degree of market development is moderate but varying with substantial opportunities for further development. These systems are very diverse and differ in constraints and potentials considerably. Where population densities are low, the systems have significant potential for agricultural growth and poverty reduction. For instance the cereal root crop FS could become a breadbasket of Africa and an important source of export earnings. Good potential has also the Mixed Maize system in eastern and southern Africa, which is currently in crisis as input use has fallen sharply due to shortage of seed, fertilizer, and agro-chemicals; and the high prices of fertilizer relative to the maize prices. As a result, yields have fallen and soil fertility is declining, while smallholders are reverting to extensive production practices. In these systems, main sources of vulnerability are market volatility, lack of improved and appropriate farming technologies, a lack of off-farm opportunities, and drought (in the drier parts). The prevalence of poverty is limited to moderate, although it can be extensive in the forest-based farming systems.

#### *Potentials for Poverty Reduction and Agricultural Growth*

The rainfed humid farming systems depend on all five household strategies for the halving of poverty. Among these strategies, diversification will be the most significant. Livestock will play a major role in diversification. Opportunities for system development lie in improved crop-livestock integration, in IPM and in improved land management techniques such as conservation farming. SLM and soil nutrient capitalization depends upon secure and equitable access to resources, especially for land and water. The development of small-scale and farmer management irrigation will contribute to both intensification and diversification.

## **Investment Note: Science and Local Innovation Make Livestock More Profitable and Environment-friendly in Latin America**

### *Summary*

Forage production and conservation are promising measures to alleviate livestock pressures on the environment. Improved forages can be economically profitable and a good option for improving the livelihoods of livestock producers. They also generate social gains because the adoption of new technologies based on improved forages generates more rural employment and increases the availability of staple foods. In the dual-purpose system it is possible to increase employment from 1.5 to 4 times. But, since few producers have the cash flow necessary to finance the required investments, farmers need to improve their farms gradually, according to the funds available. Fast, large-scale adoption needs to be coordinated with financial organizations.

There is a potential danger that farmers may wish to cut more trees to expand pastures for more cattle and profits. Further research should focus on the role of forages in matching economic and environmental sustainability through intensification and linking smallholders to markets. Research and development efforts need to proactively find ways to provide alternatives so that land degradation is no longer the most attractive land use option. Collaborative technical research with farmers that improves productivity and prevents degradation must go hand in hand with policies (e.g. taxes, payments such as for carbon, market development, media campaigns). Such linked efforts can generate incentives to change traditions and improve land management practices.

### *Key Sustainable Land Management Issues*

Changing old traditions about livestock are not easy. For generations, livestock have made money for their owners -- often with little more than a pasture. However, can earnings be increased and sustained? Livestock can cause environmental damage (Steinfeld et al. 2006). Cattle, horses, and donkeys graze not only farm pastures but in many cases, the larger landscape. What are the environmental consequences? This investment note explains how CIAT and partners combine science and local knowledge to profitably feed animals while benefiting the environment.

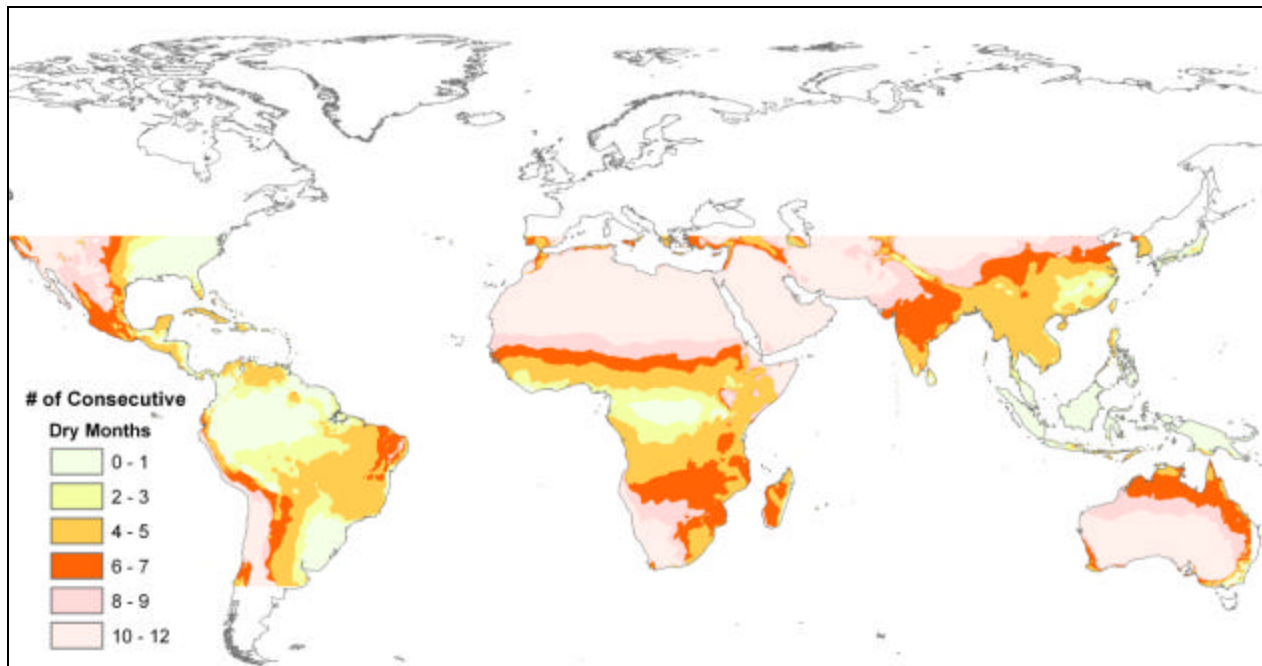
Despite much of the tropics having high annual rainfall, no rain falls for 4-7 months of the year. The landscape turns brown. During these months, livestock overgraze pastures as scarce water causes a severe shortage of livestock feed on the farm. Farmers in many areas of Latin America, Africa, and Asia, confront these water and feed challenges (figure 3.1). Here, we focus on Central America.

Damage becomes widespread. Many farmers let their livestock free to feed in the landscape. As most grasses are already dry, soon gone are the leaves of bushes and young trees. These pressures reduce plant health and vitality. Over the years, many plants die, especially the types animals prefer.

As plants disappear, soils become exposed. Annual rains return, washing away soils and further weakening the livestock landscape. With less vegetation comes a reduced ability to absorb water. The landscape is drier for more months of the year. When the rains stop, the water springs stop as well. Unchecked, this trend continues until eroded soils and weeds dominate the landscape.



**Figure 3.1 Months of Consecutive Dry Season.**



Source: CIAT

Damage also occurs to other ecologies downstream. Water flows change. The currents become more dramatic matching the rains. When the rains stop, the flows trickle. When the rains pour, the flows can overwhelm. Many people, especially in Central America, remember the pain of Hurricane Mitch in 1999.

About 45 percent of agricultural land in South America is degraded. Degradation afflicts even larger areas (74 percent) in Central America (GLASOD)<sup>1</sup>. Many inhabitants don't even notice land degradation – the story is so old. It is already part of their lives and livelihoods.

#### *Lessons Learned from Past Experience*

Despite the potential economic gain (and environmental pain), relatively few farmers see the benefit of investing in forage production for their animals. Those that invest are often pleasantly surprised with the results. They tell their friends. Details of impacts studies are below, but for now, yes, the money is good and worth looking into, as an investor would say.

For decades, CIAT scientists have developed high-yield, high nutritional quality grasses and legumes that withstand major climatic and agronomic stresses. By linking science with local perspectives, CIAT is able to apply its extensive germplasm collection of over 23,000 tropical forage varieties -- the largest collection in the world.

With partners, CIAT advances environmentally-friendly and profitable livestock production practices. This process contains four components: (1) matching forage germplasm to specific environmental conditions, (2) diagnosing farm and market contexts, (3) fostering innovation and learning processes, and (4) sharing knowledge and scaling out activities, including south-south interactions.

*Matching.* CIAT and partners have developed the ability to identify grasses and legumes that thrive in specific ecologic niches. The Selection of Forages for the Tropics knowledge management tool

(SoFT) enables not only scientists but also local extensionists and development practitioners to identify likely matches (Cook et al. 2005). SoFT is a forage selection tool with fact sheets, adaptation maps, and reference lists that is available to all on the World Wide Web web.

The more sophisticated spatial analysis tool, CaNaSTA (Crop Niche Selection in Tropical Agriculture), helps identify suitable forages according to ecologic niches, using measures of temperature, rain total, and rainfall seasonal pattern (O'Brien et al. 2005). The tool also takes into account both expert and local knowledge. Development workers and extensionists enter their local information on soils, to improve the forage--environment prediction accuracy. Precise information on soils is not widely available, particularly in heterogeneous environments where many smallholders live. Experts can update and enhance the prediction accuracy of the model. Inputs of their knowledge improve the adaptation information of specific forage varieties.

*Diagnosis.* Ecological criteria are not sufficient to ensure that nutritive forages grow on farms and appear on the landscape. Smallholder farmers want to invest in livelihood activities that show good rapid results. Especially during establishment, forages require scarce farmer resources such as their labor and money. Less-wealthy farmers who are most affected by degradation want even better pay-offs. To better understand farm contexts, CIAT scientists and partners talk with farmers. These interviews and subsequent analysis generate additional insights toward identifying a prioritized set of grasses and legumes that farmers would likely prefer (Holmann 1999; Holmann et al. 2004). From there, farmers continue the selection process on their farms.

Farmers use a range of criteria to evaluate forages and feed before using them. Table 3.1 summarizes the performance of forage species according to: (a) forage and feed characteristics (e.g., digestibility, energy content), (b) forage management and production requirements (e.g., soil type), and (c) post-harvest considerations (e.g., processing).

*Fostering* Researchers are often surprised how farmers change and adapt recommended technologies and practices. For example, CIAT and partners introduced *Cratylia* to farmers in Colombia for use as a dry season feed source to be managed as a cut-and-carry system. Farmers, however, developed several alternatives that reduced labor costs, which included direct grazing of *Cratylia* and *Brachiaria* mixtures and different cut-and-carry systems. In addition, farmers reduced establishment costs by intercropping maize, tomatoes, and cucumbers with *Cratylia*. Most surprising to researchers was the use of *Cratylia* during the wet season when pastures were waterlogged and difficult to graze.

These farmer innovations generated new research topics, such as the response of *Cratylia* to grazing and trampling, and other suitable forage intercrop combinations. In Central America, the approach of co-researching with farmers has proved effective in technology adoption (CIAT 2004). Initial impacts of collaborative research can be considered slow, but participation rapidly grows and endures with the proof of concept.

Forage processing also produces benefits to farmers. Hay and silage production enables farmers to feed their animals during the dry season. Despite significant investments in research on silage and hay production, small-scale farmer adoption of "traditional" (first generation) forage conservation methods has been low because of high investment costs, labor requirements, and limited access to technical knowledge (Mannetje 2000). To be attractive to smallholders, investments must be low cost with low risk and increase profits.

**Table 3.1 Forage Use and Production Criteria**

Crop	Forage/Feed Characteristics						Management and Production						Post-Harvest					
	Forage: grain-root-tuber/Leaf	In vitro digestibility	Protein and amino acids	Energy	Anti-nutritive compounds	Voluntary intake	Annual/ Perennial *	Drought tolerance	Adapted to low fertility soils	Time to plant maturity	Harvest interval grain/leaf (months)	Yield: Grain	Yield: Leaf	Leaf loss (rot, drop)	Continuity of Production	Potential mechanized harvest	Heat treatment (grain)	Grinding & cutting
Maize	G/l						A				5/4							
Sorghum	G/L						A				5/4							
<i>Brachiaria spp.</i>	L						P				1	n/a						
<i>Vigna unguiculata</i>	G/L		+				A				3/2							
<i>Mucuna pruriens</i>	g/L						A				5/4					?		
<i>Lablab purpureus</i>	g/L						A/p				5/4						?	
<i>Cratylia argentea</i>	L						P				-/2	n/a					n/a	
<i>Centrosema brasilianum</i>	L						P				-/4							
<i>Canavalia brasiliensis</i>	g/L						A/p				-/4						n/a	

\* requires humidity

**Legend**

	superior/preferable
	medium/acceptable/required
	inferior/undesirable

- Upper-case letter = primary use/product
- Lower-case letter = secondary use/product
- +/- = High amino acid quality/Deficiencies in amino acids
- ? = unknown
- n/a = not applicable

Source: CIAT

An alternative for ensiling forages is use of plastic bags, coined as “little bag silage” (LBS) by Lane (2000). LBS conserves of small quantities of fodder with reduced risk of fermentation. High-quality legume hay can also be packed and sold in plastic bags. Other technologies include storage in earth silos or larger size plastic bags.

*Sharing and scaling.* Effective expansion of research results to smallholder farmers requires information exchange and ample seed. Numerous methods enhance dialogue between farmers that include farmer field days, exchange visits and knowledge sharing between countries. For example, Nicaraguan moulds that ease the bag filling process are now adapted and employed by farmers in

Honduras and Colombia. Both the private seed sector (i.e., the Mexican seed enterprise Papalotla) and small-scale enterprises produce seed for widespread distribution (CIAT 2007).

#### *Opportunities for Sustainable Land Management: Products and Services*

Many forages grow well in areas prone to drought and with low soil fertility. Leguminous forages are of particular interest as they fix nitrogen, thereby contributing to system sustainability (Schultze-Kraft and Peters, 1997; Shelton, et al. 2005). Improved pasture and forage management enables farmers to change their land uses, thereby generating positive environmental benefits.

System intensification with improved forages and soil conservation technologies increases productivity per animal. Intensification, from the SLM perspective, increases the productivity of land or carrying capacity of land. Other environmental benefits of improved forages include higher organic matter of soils, higher manure quality and increased agricultural productivity, (Giller 2001; Schultze-Kraft and Peters 1997). An emphasis is placed on highly productive and drought tolerant materials, to achieve permanent vegetation cover, thus erosion risks are reduced. Cut-and-carry systems can decrease pressure on areas unsuitable for grazing such as steep slopes and forests (Cruz et al. 2003; Schmidt and Peters 2003). Landscape benefits of forages include improved water resources- quantity and quality. Moreover, intensification through increased productivity can reduce greenhouse gas emissions from deforestation and pasture degradation (Steinfeld et al. 2006).

#### **Box 3.1. Example of Pasture Rehabilitation and Intensification from Honduras**

The Nuñez are smallholder farmers in Yorito, Honduras. For years, they obtained only 35 liters of milk per day from their 12 cows that fed on low-quality grasses. Pastures included a deforested area in the upper portion of their farm. With help from CIAT and national technicians, the Nuñez planted *Brachiaria brizantha* Toledo, the hybrid *Brachiaria* Mulato, and the legume shrub *Cratylia argentea*. Management innovations included cut-and-carry forages, pasture rotations and silage production systems that were appropriate to their smallholder farming system. These changes ensured an ample supply of high-quality fodder during the dry season. The new feeding approach generated both private financial and public environmental benefits. Milk production increased to 75 liters per day on less pasture, animals gained significant weight, and reproductive rates improved. Since their herd increased to 25 head, they planted more forage materials and constructed a 64 m<sup>3</sup> brick silo. Increased income from the additional milk has already paid for most of the new investments and will enable them to diversify into new activities. Meanwhile, the more intensive production system let the family revert steeply-sloped pastures back to forest, and thereby protect an important local water source.

*Source:* CIAT

#### *Rationale for Investment*

Forage production and conservation are promising measures to alleviate livestock pressures on the environment (Peters et al. 2001). Especially in Central America, system intensification through improved forages is attractive to farmers. Improved forages are economically profitable and represent a good option to improve the livelihoods of livestock producers (Holmann and Rivas 2005). Adopting *Brachiaria* for direct grazing during the rainy season with the shrub legume *Cratylia argentea* for feeding during the dry season can significantly improve milk and beef productivity. The number of cows can be increased between 2.1 and 3.5 times in the dual-purpose system and between 2.6 and 6 times in the specialized beef system. Milk production can increase from 2.3 to 3.5 times in the dual-purpose system. The investments in improved forages not only brings economic benefits for producers, but also social gains because the adoption of new technologies based on improved forages generates more rural employment and increases the availability of staple foods. In the dual-purpose system it is possible to increase employment from 1.5 to 4 times. Investments are economically profitable and represent a good option to improve the livelihoods of livestock producers (Holmann and Rivas 2005).

Nevertheless, investments require ample funds or a line of credit over several years (i.e., 2-7, depending on the production system and macroeconomic conditions). Because few producers have the cash flow necessary to finance the required investments, farmers need to improve their farms gradually, according to the funds available. Fast, large-scale adoption needs to be coordinated with financial organizations.

When something works, why not do more? That is a potential danger by making livestock production more profitable. Farmers may wish to cut more trees to expand pastures for more cattle and profits. The SLM challenges continue. Nevertheless, not all farmers do so. CIAT researchers have learned about the impacts of improved forages.

The environmental impacts of improving forage production are mixed but largely predictable (White et al. 2001). If land is expensive, it is cheaper to intensify production than to extend pastures into forest and other areas. Farmers tend to improve their pastures forages. Problems arise when land is inexpensive. In such areas, land can cost less than a bag of fertilizer. Therefore, it is more logical to expand pastures into the forest than to improve production of existing pastures. Land becomes expensive when scarce and or productive. To make land scarce, access need to be restricted. Policies to protect forests can achieve that aim, again with mixed results (Angelsen and Kaimowitz 2001). Local institutions can be fostered encourage sustainable land management.

The potential of improved forages in mitigating effects of expanding livestock production and improving agro-ecosystem health are not yet fully explored. Thus, further research should focus on the role of forages in matching economic and environmental sustainability through intensification and linking smallholders to markets.

Although the contributions of forages soil resources are many (e.g., improved nitrogen fixation, soil organic matter buildup, enhanced soil biological activity and below-ground biodiversity, improved manure quality, increased productivity of subsequent crops), the exact quantification and assessment of economic impacts require further research. Other challenges include smallholder cut-and-carry systems with very limited external inputs. System nutrient balances are 2<sup>nd</sup> generation problems that need to be addressed.

#### *Recommendations for Practitioners*

Livestock have been and will continue to be part of the landscape in Latin America. Matching forage germplasm with farmer preferences requires coordination between research, development and policy. Effective efforts contain four components: (1) targeting according to biophysical conditions, (2) diagnosing farm and market contexts, (3) fostering innovation and learning processes, and (4) sharing knowledge and scaling out, including south-south interactions.

Research and development efforts need to proactively find ways to improve the feasibility of adopting forage technologies. Future research should provide alternatives so that land degradation is no longer the most attractive land use option. To speed adoption processes, collaborative technical research with farmers that improves productivity and prevents degradation must go hand in hand with policies (e.g., taxes, payments such as for carbon, market development, media campaigns). Such linked efforts can generate incentives to change traditions and improve land management practices.

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### **Web Resources**

[www.ciat.cgiar.org/](http://www.ciat.cgiar.org/)  
<http://www.tropentag.de/2003/pdf/proceedings.pdf>  
<http://www.virtualcentre.org/>  
[www.utaoundation.org/lrrd1611/holm16090.htm](http://www.utaoundation.org/lrrd1611/holm16090.htm)  
<http://www.cipav.org.co/lrrd/lrrd11/3/hol113.htm>  
<http://www.odi.org.uk/agren/publist.html>  
[www.tropicalforages.info](http://www.tropicalforages.info)

This Note was prepared by M. Peters and D. White, CIAT, Cali, Colombia; and F. Holmann, CIAT and the International Livestock Research Institute (ILRI), Cali, Colombia.

## **Investment Note: An Approach to Sustainable Land Management through Enhancing the Productive Capacity of African Farms – The Case of the Underutilized and Versatile Soybean.**

### *Summary*

Soybeans can improve soil fertility but, in Africa, few farmers plant them. Crops grown after soybean can produce larger harvests for household consumption or market sale due to the nitrogen-fixing capacity of the crop (but note the caveat regarding the important differences between conventional soya – which leaves little for the following crop and sends most of the nitrogen to the grain – and promiscuous soya which leaves much more nitrogen in the soil). The use of soybean within an agricultural system also enables farmers to diversify production, thereby spreading their exposure to risk across different crops. Since on-farm investments are minimal, resource-poor farmers can begin production easily and the crop is attractive to women – both as a crop for sale and for home consumption. TSBF-CIAT has developed a soybean promotion initiative based around strategic alliances to support market development and utilisation information for soybean. The approach recognizes that successful diversification requires cooperation among farmers and between farmers and service providers to build a viable market chain. Dialogue amongst the market chain participants and service providers helps to generate better understanding of each other's needs and challenges.

### *Key Sustainable Land Management Issues*

Soil nutrient losses in sub-Saharan Africa are an environmental, social, and political time bomb. Unless we wake up soon and reverse these disastrous trends, the future viability of African food systems will be imperiled (Borlaug 2003). Soil degradation is one of the major constraints to achieving food security in developing countries, particularly in Africa.

Degradation may pay in the short term but not in the long. Unfortunately, much of Africa is experiencing the long-term effects of degradation (Anderson, et al. 2003). Abundant yields do not continue without adequate investments in soil fertility. Many farmers are caught in a poverty trap (Barrett, et al. 2004) where harvests are insufficient to meet urgent household food needs – let alone generate enough income to invest in fertilizers. Moreover, chemical fertilizers are too expensive (Camara and Heinemann, 2006). Organic resources sufficient to replenish nutrient losses through cropping are difficult to produce (African Fertilizer Summit, 2006). The effects of land degradation are felt beyond the farm. As productivity declines, families often expand production into new areas.

Soybeans can improve soil fertility. In Africa, however, few farmers plant them. Coordinated research and promotion activities are needed to enable soybeans to become a valuable crop within smallholder agricultural systems. This investment note shares the experience of the Tropical Soil Biology and Fertility Institute of the Centro Internacional de Agricultura Tropical (TSBF-CIAT) and partners in advancing soybean in Kenya. Only by adequately addressing aspects of production, processing and consumption, can soybeans help improve both household earnings and land productivity.

### *Lessons Learned from Past Experiences*

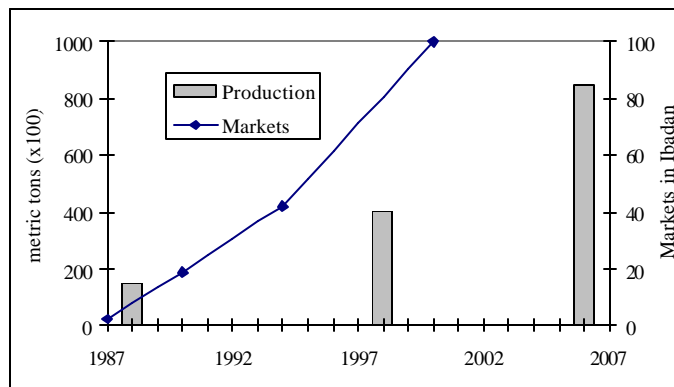
Soybean can add nitrogen to soils (although the conventional varieties channel most nitrogen to the grain and leave little to be returned to the soil). An important development has been the breeding of 'promiscuous' soybean. Promiscuous varieties nodulate with the natural soil bacteria rather than with the highly variety specific bacteria which typically have to be provided at planting with conventional soya. Promiscuous varieties are typically slightly lower in yield but return a significantly higher



amount of nitrogen to the soil. For smallholders, where nitrogen is a scarce and expensive input, promiscuous soya are both easier to grow and add greater fertility to the overall production system. By cultivating soybean, farmers can harvest valuable grains while improving the productive capacity of their farms. Such a positive outcome, however, is not always achieved. Only some efforts to promote soybean have been successful; perhaps this is why soybean remains a minor crop in African farming systems.

In Nigeria, the International Institute of Tropical Agriculture (IITA) and Canada's International Development Research Center (IDRC) implemented a comprehensive and successful soybean project between 1987 and 1999. During that time, soybean production increased from about 150,000 to 405,000 tons, an increase of 166 percent (FAO 2001). Average yields more than doubled from about 340 to 740 kg ha.<sup>-1</sup> Village surveys confirmed dramatic soybean production increases in Benue State. The annual production of 70 soybean farmers (a random sample) was less than 5 tons between 1982 and 1984, but increased to 30 tons by 1989 (Sanginga 1999). Presently, Nigeria produces about 850,000 metric tons of soybean annually (figure 3.2).

**Figure 3.2 Nigerian Soybean Production (1988 - 2006) and Markets in Ibadan (1987-2000)**



Source: FAO 2001; Mpepereki.

Increasing demand for soybean encouraged production and was crucial to project success. An urban market survey in Ibadan (one of Nigeria's largest cities) revealed that only two markets sold in soybean in 1987, and increased over 100 by the year 2000 (See figure 3.2). Soybean retailers in these markets expanded from 4 to over 1,500 between 1987 and 1999. A similar success also occurred in Zimbabwe following a project intervention led by University of Zimbabwe (Blackie, 2006; Mpepereki, personal communication).

In stark contrast, soybean promotion in Kenya generated few positive results. Despite the contribution of many national and international organizations, soybean production and consumption has not achieved widespread impacts. The main reasons for the failure were: (1) a lack of awareness about soybean processing and utilization, (2) low yields, and (3) few markets.

#### *Opportunities for Sustainable Land Management*

Because soybean cultivation can fix as much as 100 kg of nitrogen per hectare (Sanginga et al., 2003) (but note the caveat regarding the important differences between conventional soya – which leaves little for the following crop and sends most of the nitrogen to the grain – and promiscuous soya which leaves much more nitrogen in the soil), crops grown after soybean produce larger harvests for household consumption or market sale. The use of soybean within an agricultural system also enables farmers to diversify production, thereby spreading their exposure to risk across different

crops. Such a farm management strategy minimizes the possibility of catastrophic harvest losses at the farm household and landscape level.

In western Kenya, maize is commonly intercropped with common beans. The major cash crops in the area are sugarcane, tobacco, and cotton. Soybean fits into the maize-base cropping system and is currently either intercropped with maize or rotated with maize. Kenyan scientists have developed the Mbili intercropping system which greatly increases the efficiency and productivity of maize intercropping. By skillfully altering the spacing both between and within rows of tall growing maize while maintaining overall plant population, the lower growing extra intercrop gains extra light and thus yields better – without compromising the yield of the major food crop, maize. Farmers also intercrop soybean with sugarcane. In addition, soybean enables resource-poor farmers to take advantage of the nitrogen-fixing attributes of the promiscuous soybean varieties for their subsequent maize. This effect has been dramatic, especially where two seasons of soybean are followed by one season of maize.

#### *Rationale for Investment*

Good food, nice profit, and better soil fertility are key motivators to cultivate soybean. Improved and sustainable land management comes as a welcome bonus. With positive incentives such as households liking its taste and market paying attractive prices, the secondary benefits of soil fertility can easily tag along.

Soybean is also an important cash crop with many uses. Since the 1960s, the plant has been the dominant oilseed (Smith and Huyser 1987). It is a human food, livestock feed and has numerous industrial purposes (Myaka et al. 2005). The 40 percent protein content of soybean is approximately twice that of other legumes (Greenberg and Hartung 1998). Despite these apparent uses and benefits, soybean production in Africa remains low. In 2000, sub-Saharan Africa cultivated only 1 percent of the world's soybean.

Soybean cultivation enhances social benefits and gender equity. Because on-farm investments are minimal, resource-poor farmers can begin production easily. Besides preparing meals with soybean, many women get involved in soybean production (Sanginga et al. 1999).

A recent initiative fostered by TSBF-CIAT aims to broaden the exposure of rural households to soybean in Kenya. The new initiative aims to: (a) capture and hold the interest of farmers in soybean through an information campaign (to dispel unfounded myths and emphasize benefits), and (b) create a desire amongst farmers to process and consume soybean in different forms through training in processing.

Project partners include the Kenya Agricultural Research Institute, Kenyatta University, the Lake Basin Development Authority, the Kenya Forestry Research Institute, the International Maize and Wheat Improvement Center (CIMMYT), and the International Institute for Tropical Agriculture (IITA). Strategic alliances of important stakeholders in soybean production-to-consumption chain are central to the project. TSBF-CIAT has developed a “three-tier approach for sustainable soybean promotion” for Kenya, described as follows:

*Tier 1 Household level:* The approach begins with the creation of widespread awareness on various benefits of soybean production, consumption, and marketing and practical training. From the beginning, the project confronts unfounded common household myths and stereotypes about soybean – wrong impressions that can undermine an initiative if not adequately addressed with compelling evidence and practical demonstrations. Participatory development of soybean products emphasizes the ease of use within popular local dishes.

*Tier 2 Community level:* Surpluses of soybean production at household-level are absorbed at the community level and processed into: soymilk, yogurt, soy bread, cakes, biscuits, etc. Processing can absorb household-level production surpluses that could otherwise become a disincentive to further cultivation. Tier 2 also creates new consumer preferences and potential demand through the creation of new products (e.g., soymilk, soy yogurt, meat substitutes).

*Tier 3 Industry level:* This tier continues the formalization of soybean producer in the market. The main emphasis is to link soybean producers with input suppliers (i.e., seed, fertilizer, value addition knowledge, information, transport, etc.) and output purchasers, especially the industrial market. The project interacts with numerous actors of the supply chain, including: (a) industry, to find out what they want, (b) farmers, to evaluate their ability to deliver products that meet industrial specifications, and (c) other stakeholders to determine how they can contribute to the market development process.

#### *Recommendations for Practitioners*

Strategic alliances support the three-tier market development for soybean. Project partners enable smallholder farmers to benefit from soybean production by providing diverse types of necessary and complementary support. The approach recognizes that successful diversification requires cooperation among farmers and between farmers and service providers to build a viable market chain. Dialogue amongst the market chain participants and service providers helps to generate better understanding of each other's needs and challenges. Different types of knowledge are shared: research, technology, production, equipment, transport, and support services (CIAT 2005). The strategic alliance has eight types of actors whose participation is crucial for successful soybean promotion:

##### *1. Soybean farmers/farmer associations*

Farmer representatives are responsible for interacting with other farmers in order to articulate their views during the alliance meetings. Through the process of consolidating relationships with buyers and opening communication channels with all market chain participants, farmers gain valuable experience and confidence, which in turn enhances their negotiating power.

##### *2. Input suppliers*

A common feature of the soybean farmers is lack of capital and inputs such as appropriate germplasm. Input service providers include agricultural input and seed suppliers and micro-credit agencies.

##### *3. Non-governmental organizations*

NGOs provide assistance on post-production value added activities: (i.e., sorting, bulking, grading, packaging, transportation, haulage, and storage). These activities enable farmers to increase prices received.

##### *4. Food processors*

Large-scale industries currently import soybean. Provided that farmers produce the grains of the quality desired, these industries reaffirm their commitment to purchase produced grain at agreed prices.

##### *5. Communication/information agencies*

Due to the critical role of information, grassroots information/communication agency, *AfriAfya*, is in the alliance to backstop extension and strengthen the provision of information and communication

services and soybean technologies. *AfriAfya* is responsible for creating local content that responds to the needs of rural people.

#### *6. Government institutions*

The key government institutions represented in the alliance may include the Ministries of Agriculture, Trade and Industry, and Finance. These institutions assist with both implementation and the formulation of enabling policies in support of soybean.

#### *7. Donor organizations*

Organizations such as the Rockefeller Foundation provide funds for organizing and implementing the alliance.

The alliance ensures: (a) creating an opportunity for integrated resource mobilization, (b) involving each stakeholder within a larger problem-solving framework, (c) providing assistance in analyzing distinct perceptions of different actors, (d) strengthening capacity of business services, (e) effectively brokering and addressing industry needs, and (f) developing enduring public–private partnerships for long-term success.

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## **Web Resources**

[http://www.ciat.cgiar.org/tsbf\\_institute/index.htm](http://www.ciat.cgiar.org/tsbf_institute/index.htm)

[http://www.ifdc.org/PDF\\_Files/LS-3%20Feeding%20a%20World%2010%20Billion.pdf](http://www.ifdc.org/PDF_Files/LS-3%20Feeding%20a%20World%2010%20Billion.pdf)

<http://www.basis.wisc.edu/live/basbrief24.pdf>

[www.usaid.gov/our\\_work/agriculture/landmanagement/pubs/nature\\_wealth\\_power\\_fy2004.pdf](http://www.usaid.gov/our_work/agriculture/landmanagement/pubs/nature_wealth_power_fy2004.pdf)

<http://www.africafertilizersummit.org/FAQ.html>

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## **Investment Note: Balancing Rainforest Conservation and Poverty Reduction**

### *Summary*

The Alternatives to Slash and Burn (ASB) program comprises a global alliance of over 80 local, national and international partners dedicated to action-oriented integrated natural resource management (iNRM) research in the tropical forest margins.

ASB research in Indonesia and Cameroon have revealed the feasibility of a ‘middle path’ of development involving smallholder agroforests and community forest management for timber and other products. The Brazilian Amazon, in contrast, presents much starker tradeoffs between global environmental benefits and the returns to smallholders’ labor. Here the most commonly practiced pasture–livestock system, which occupies the vast majority of converted forest land, is profitable for smallholders (at least in the short term) but entails huge carbon emissions and biodiversity loss. The land use alternatives that are attractive privately are at odds with global environmental interests.

Results from ASB research at all the benchmark sites show that it is futile to attempt to conserve forests in developing countries without addressing the needs of poor local people. The issues are well illustrated by a study of options facing settlers in Brazil’s Acre State. Using a specially developed bioeconomic model, ASB researchers showed that only in the unlikely event that prices quadrupled over their current level might the rate of deforestation slow. Even in this case the braking effect is slight and the modest saving in forest would probably be short-lived.

### *Key Sustainable Land Management Issues*

Occasionally it is possible to conserve tropical forests while reducing poverty, but more often these two objectives conflict. Without action to resolve this conflict, tropical forests will continue to disappear. Striking an equitable balance between the legitimate interests of development and equally legitimate global concerns over the environmental consequences of tropical deforestation is one of the greatest challenges of our generation.

Everyone in the world wants something from tropical forests. Forest dwellers wish to continue their traditional way of life based on hunting and gathering. They are losing their land to migrant smallholders, who clear small amounts of forest to earn a living by raising crops and livestock. Both these groups tend to lose out to larger, more powerful interests—ranchers, plantation owners, large-scale farmers or logging concerns—whose aim is to convert large areas of forest into big money. Outside the forests is the international community, who wishes to see forests’ preserved for the carbon they store; that would otherwise contribute to global warming, and for the wealth of biological diversity they harbor.

Deforestation continues because converting forests to other uses is almost always profitable for the individual. However, society as a whole bears the costs of lost biodiversity, global warming, smoke pollution and the degradation of water resources.

Every year the world loses about 10 million hectares of tropical forest — an area more than three times the size of Belgium. None of the land-use systems that replace this natural forest can match it in terms of biodiversity richness and carbon storage. However, these systems do vary greatly in the degree to which they combine at least some environmental benefits with their contributions to economic growth and poor peoples’ livelihoods. It is, therefore, always worth asking what will replace forest (and for how long), both under the current mix of policies, institutions, and technologies and compared to possible alternatives. In other words, what can be done to secure the best balance among the conflicting interests of different groups?

### *Integrated Natural Resources Management Approach*

The Alternatives to Slash and Burn (ASB) program comprises a well-established global alliance of over 80 local, national, and international partners dedicated to action-oriented integrated natural resource management (iNRM) research in the tropical forest margins. It is the only global partnership devoted entirely to research on the tropical forest margins. It is the goal of ASB to raise productivity and income of rural households in the humid tropics without increasing deforestation or undermining essential environmental services. ASB applies an integrated natural resource management (iNRM) approach to analysis and action through long-term engagement with local communities and policy makers at various levels.

### *Key Drivers for Degradation Dynamics-The ASB Matrix: Lining Up the Facts*

Faced with such questions, policy makers need accurate, objective information on which to base their inevitably controversial decisions. To help them weigh up the difficult choices they must make, ASB researchers have developed a new tool known as the ASB matrix (Figure 3.3)

In the ASB matrix, natural forest and the land-use systems that replace it are scored against different criteria reflecting the objectives of different interest groups. To enable results to be compared across locations, the systems specific to each are grouped according to broad categories, ranging from agroforests to grasslands and pastures.

The criteria may be fine-tuned for specific locations, but the matrix always comprises indicators for:

- Two major global environmental concerns: carbon storage and biodiversity;
- Agronomic sustainability, assessed according to a range of soil characteristics, including trends in nutrients and organic matter over time;
- Policy objectives: economic growth and employment opportunities;
- Smallholders' concerns: their workload, returns to their labor, food security for their family, and start-up costs of new systems or techniques;
- Policy and institutional barriers to adoption by smallholders, including the availability of credit, markets, and improved technology.

Over the past 8 years, ASB researchers have filled in this matrix for representative benchmark sites dotted across the humid tropics. Political and economic factors at work at these sites vary greatly, as also does their current resource endowment: from the densely populated lowlands of the Indonesian island of Sumatra, through a region of varying population density and access to markets south of Yaoundé in Cameroon, to the remote forests of Acre State in the far west of the Brazilian Amazon, where settlement by small-scale farmers is relatively recent and forest is still plentiful.

At each site, ASB researchers have evaluated land-use systems both as they are currently practiced and in the alternative forms that could be possible through policy, institutional, and technological innovations. A key question addressed was whether the intensification of land use through technological innovation could reduce both poverty and deforestation.



**Figure 3.3. ASB Summary Matrix: Natural forest and the land-use systems that replace it are scored against criteria that are important for the diverse range of stakeholders in the landscape\***

ASB Summary Matrix: Forest Margins of Sumatra						
Land-use	Global environment		Agronomic sustainability	National policymakers' concerns		Adoptability by smallholders
	Carbon sequestration	Biodiversity	Plot-level production sustainability	Potential profitability (at social prices)	Employment	Production incentives (at private prices)
	Aboveground, Time-averaged (tonnes/ha)	Aboveground, Plant species/standard plot	Overall rating	Returns to land (US\$/ha)	Average labour input (days/ha/yr)	Returns to labour (US\$/day)
Description						
Natural forest	306	120	1	0	0	0
Community-based forest management	136	100	1	11	0.2	4.77
Commercial logging	93	90	0.5	1080	31	0.78
Rubber agroforest	89	90	0.5	506	111	2.86
Oil palm monoculture	54	25	0.5	1653	108	4.74
Upland rice/bush fallow rotation	7	45	0.5	(117)	25	1.23
Continuous cassava degrading to <i>Imperata</i>	2	15	0	28	98	1.78

\* These criteria include global environmental benefits, agronomic sustainability, profitability, labor, and incentives  
 Source: Tomich et al., 1998.

### *Lessons Learned from Past Experiences*

The matrix allows researchers, policymakers, environmentalists and others to identify and discuss tradeoffs among the various objectives of different interest groups.

The studies in Indonesia and Cameroon have revealed the feasibility of a ‘middle path’ of development involving smallholder agroforests and community forest management for timber and other products. Such a path could deliver an attractive balance between environmental benefits and equitable economic growth. Whether or not this balance is struck in practice, however, will depend on the ability of these countries to deliver the necessary policy and institutional innovations.

Take the examples of Sumatran rubber agroforests and their cocoa and fruit counterparts in Cameroon. These systems offer levels of biodiversity which, though not as high as those found in natural forest, are nevertheless far higher than those in single species tree plantations or annual cropping systems. Like any tree-based system, they also offer substantial levels of carbon storage. Crucially, technological innovations have the potential to increase the yields of the key commodities in these systems, thereby raising farmers’ incomes substantially, to levels that either outperform or at least compete well with virtually all other systems. However, to realize this potential, it will be vital to find ways of delivering improved planting material — the key input needed.

The Brazilian Amazon, in contrast, presents much starker tradeoffs between global environmental benefits and the returns to smallholders’ labor. Here the most commonly practiced pasture–livestock system, which occupies the vast majority of converted forest land, is profitable for smallholders but entails huge carbon emissions and biodiversity loss. Systems that are preferable to this one from an environmental point of view, such as coffee combined with *bandarra* (a fast-growing timber tree), can pay better, but have prohibitively high start-up costs and labor requirements and are riskier for farmers. An alternative pasture–livestock system, in which farmers are expressing interest, offers

even higher returns to land and labor but only slightly improves biodiversity and carbon storage (see below). In other words, the land use alternatives that are attractive privately are at odds with global environmental interests. Only a radical overhaul of the incentives facing land users, including smallholders, could change things.

Just how radical would the overhaul have to be? Very radical – even for a small effect --according to ASB research. Consider the gathering of wild Brazil nuts, one of the most environmentally benign uses of the Amazon's forests. At current prices offered to smallholders, Brazil nut harvesting pays well below the going rate for wage labor. To persuade smallholders merely to slow the pace of deforestation, the price of nuts would have to rise more than fourfold.

Research by ASB scientists of the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) on the pasture–livestock system in the western Amazon of Brazil shows that, with a combination of legumes to enrich pastures and solar-powered electric fences to control the pattern of grazing by their cattle, smallholders could double milk production per cow and triple the carrying capacity of their land, bringing a marked increase in profitability. And since this pasture system is sustainable without annual burning to control weeds, seasonal smoke pollution would be reduced (see ASB web resources link below – Policy Brief No. 4).

So why haven't these practices been adopted widely already? First, the vast majority of smallholders cannot get access to the necessary credit, seeds or hired labor and are too far from markets to be able to sell the increased milk supplies. Second, aiming for these higher profits entails increased risk, in part because of the higher initial investment costs. But even if these barriers were eliminated, widespread adoption of such improvements would likely increase — not decrease — the pressure on neighboring forests. The reason is that the greater profitability of the improved system would make the agricultural frontier more attractive to new settlers. Thus, under the present mix of policies and institutions, and the incentives they create, the forests in Brazil's western Amazon will continue to fall whether the smallholder succeeds or fails.

#### *Opportunities for Sustainable Land Management: Products and Services*

Based on these results, what can be done to balance the objectives of forest conservation and poverty reduction in these tricky settings?

Some assert the best opportunities for meeting both objectives lie in the harvest of various products from community managed forests. In practice, such extensive systems require low population densities plus effective mechanisms for keeping other groups out if they are to prove sustainable.

Where forests are converted, agroforests often represent the “next best” option for conserving biodiversity and storing carbon, while also providing attractive livelihood opportunities for smallholders. However, for both economic and ecological reasons, no single land use system should predominate at the expense of all others. Mixes of land uses increase biodiversity at a landscape level, if not within individual systems, and also can enhance economic and ecological resilience. A mixed ‘landscape mosaic’ represents an especially attractive option in cases such as Brazil, where no single system offers a reasonable compromise between different objectives.

Where productivity of the natural resource base has already sunk to very low levels, concentrating development efforts on the simultaneous environmental and economic restoration of degraded landscapes is an option that is well worth exploring.

The precise mix of interventions needed — hence the benefits and costs of restoration — varies from place to place. In Cameroon, improved cocoa and fruit tree systems could be a win-win

proposition in place of unsustainably short fallow rotations. In Indonesia, millions of hectares of *Imperata* grasslands are the obvious starting point.

The direction of change in land-use systems determines the environmental consequences. For example, if farmers replace unsustainable cassava production with an improved rubber agroforest, they help restore habitats and carbon stocks. But if such a system replaces natural forest, the environment loses. Intensification of land use through technological change is a two-edged sword. It has great potential to increase the productivity and sustainability of existing forest-derived systems, thereby raising incomes. By the same token, however, these higher incomes attract more landless people to the agricultural frontier in search of a better living. Therefore, technological innovation to intensify land use will not be enough to stop deforestation. Indeed, it often will accelerate it. If both objectives are to be met, policy measures intended to encourage intensification will need to be accompanied by measures to protect those forest areas that harbor globally significant biodiversity.

#### *Rationale for Investment*

The main point for policy makers is that, without tangible incentives linked to the supply of global environmental benefits, people will continue to cut down tropical rainforests. Results from ASB research at all the benchmark sites show that it is futile to attempt to conserve forests in developing countries without addressing the needs of poor local people. But how can the necessary incentives to conserve be put in place? Only a limited number of policy instruments have so far been tried and there is still much to learn about what does and does not work. Part of the answer lies in the developing countries themselves, where such measures as securing land tenure and use rights can be taken. But should these countries have to shoulder the entire financial burden of forest conservation when all face urgent development imperatives, such as educating and vaccinating rural children?

The bottom line is that, if the international community wants the global benefits of rainforest preservation, it is going to have to pay for some of the costs.

#### *Recommendations for Practitioners*

##### The Case of Brazil Nuts

The issues are well illustrated by a study of options facing settlers in Brazil's Acre State. These farmers clear forest gradually over the years, with pasture for cattle becoming the dominant land use. In addition, around 50 percent of farm families harvest nuts from the part of their farms that remains forested.

Using a specially developed bioeconomic model, ASB researchers explored how labor, capital and land would be allocated to different on-farm activities over a 25-year period under different price and market scenarios. When they applied the model to Brazil nuts, the researchers found that doubling the farmgate price of nuts would not decrease and might even increase the rate of deforestation. The reason is that farmers probably would re-invest the extra cash they earned in clearing forest faster. From the farmers' perspective, even at the higher price, cattle production remains by far the more profitable activity. Only in the unlikely event that prices quadrupled over their current level might the rate of deforestation slow. Even in this case the braking effect is slight and the modest saving in forest would probably be short-lived.

The researchers concluded that subsidizing the price of Brazil nuts would not by itself be an effective policy measure for conserving forests.

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## **Web Resources**

<http://www.worldagroforestry.org/es/default.asp>

<http://www.worldagroforestry.org/sea/Networks/RUPES/index.asp>

<http://www.asb.cgiar.org/>

<http://www.asb.cgiar.org/publications/policybriefs>

<http://www.asb.cgiar.org/publications/asbvoices/>

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## **Investment Note: Groundwater Declines and Land Use: Looking for the Right Solutions**

### *Summary*

Countries are increasingly relying on finite groundwater reserves (built up over centuries) for household, agricultural, and industrial needs. Although addressing water shortages in the short term, groundwater exploitation brings with it its own host of problems. To solve these, it is necessary to conduct holistic studies of hydrologic systems to find appropriate solutions that will result in real water savings.

The North China Plain is China's most important agricultural centre, producing more than half the country's wheat and a third of its maize. The deficit between rainfall and crop requirements has been met by irrigation from aquifers underlying the plain. Pumping water from the aquifers has led to the continued decline of groundwater levels despite improved irrigation efficiency and reduced pumping.

IWMI's study used a water balance approach - a simple accounting method used to quantify hydrologic changes. The model shows clearly that simply changing the amount of water applied for irrigation will not affect the rate of groundwater depletion - this leaves only the only two other variables of rainfall and evapotranspiration. With rainfall beyond management control, the only way to reduce groundwater depletion and to achieve real water savings is to address evapotranspiration. The water balance approach enabled the formulation of successful water saving choices. The sets of options are made up of a combination of changing cropping patterns, leaving certain areas of land to lie fallow, and change of land use to urban uses. Each set of options is a different combination of land uses that will deplete no more than 460 mm/yr—bringing the rainfall and evapotranspiration into equilibrium.

### *Key Sustainable Land Management Issues*

With growing populations, changing weather patterns, and increasing pollution of surface water bodies, countries across the world are relying more and more on finite groundwater reserves built up over centuries, for household, agricultural, and industrial needs. Although addressing water shortages in the short term, groundwater exploitation brings with it its own host of problems. It can cause surface-water depletion, salt water intrusion into fresh water aquifers, and subsidence of the land surface (Box 3.2). Governments are quick to turn to improving water efficiency as the best solution to the problem, but are too often disappointed. Research is increasingly highlighting that in devising water management strategies to conserve water and halt the decline of groundwater levels, policy makers must conduct holistic studies of hydrologic systems to find appropriate solutions that will result in real water savings. What's needed then is not a simple "one size fits all" policy or solution, but varying management approaches to suit specific situations. The concept of hydronomic zones, which categorizes a hydrologic system into different zones—each having its own best set of water saving measures —could be a useful tool in this exercise.

### **Box 3.2 Examining Hydrological Contradictions in the North China Plain**

The North China Plain is China's most important agricultural centre, producing more than half the country's wheat and a third of its maize. It is 320,000 km<sup>2</sup> in extent and home to more than 200 million people. It is bordered by mountains on the west and the Yellow Sea on the east. Three rivers drain into the plain (fig.1). The climate is temperate and monsoonal, with cold, dry winters and hot, humid summers. The shortage, and seasonal distribution, of water are two key factors that inhibit agriculture. Annual rainfall averages between 500 mm in the north and 800 mm in the south. The typical winter wheat/summer maize cropping pattern currently practiced consumes 660mm to 920mm of water annually. The deficit between rainfall and crop requirements has been met by irrigation from aquifers underlying the plain. Pumping water from the aquifers has led to the continued decline of groundwater levels despite improved irrigation efficiency and reduced pumping.

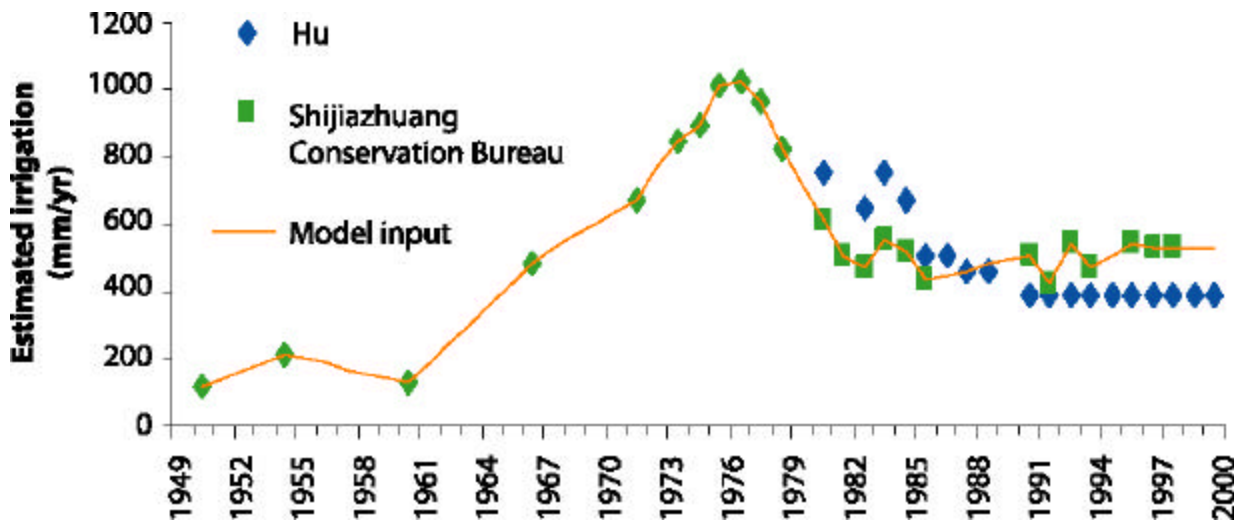
The paradox of increasing irrigation efficiency and reduced pumping yet declining groundwater levels highlighted in Box 3.2 above, has puzzled water policy experts and resource managers. It provided the impetus for an International Water Management Institute (IWMI) study (Kendy et al. 2003) in the Luancheng County located in the Hai River basin, one of the three rivers draining the North China Plain. The study examined the nexus between agricultural policies in the area, water management approaches, and actual water use, in an effort to explain the steady decline in groundwater levels and to find appropriate solutions to halt this decline.

#### *Trends in Resource Use*

As agricultural policies and water management strategies evolved over the years, water use trends also changed accordingly. With increased winter wheat cropping and a shift from cotton to more irrigation intensive maize, an increase in groundwater use that would mirror the cropping patterns could be expected. However, the reality is quite different. Contrary to expectations, groundwater pumping did not increase with the increase and change in cropping. Even more surprisingly, pumping rates actually decreased during the late 1970s to the early 1980s before finally stabilizing in the 1980s (figure 3.4). Nevertheless, there has been a steady decline in groundwater levels throughout the period under study. This seeming contradiction has puzzled water policy experts and resource managers and provided the impetus for IWMI's study (Kendy et al, 2003) in the Luancheng County located in the Hai River basin, one of the three rivers draining the North China Plain . The study examined the nexus between agricultural policies in the area, water management approaches, and actual water use, in an effort to explain the steady decline in groundwater levels and to find appropriate solutions to halt this decline.



**Figure 3.4 Irrigation History of Luancheng County, 1949-1999: Estimated Pumping for Irrigation**



Note. 'Pumping' in the 1950s was primarily hauling, rather than pumping, from shallow, brick-lined wells. 'Model Input' indicates groundwater pumping and irrigation values used to calculate annual water balances.

Sources: Hu, Chanseng, Chinese Academies of Science, personal communication; Shijiazhuang Water Conversion Bureau (1949-1999).

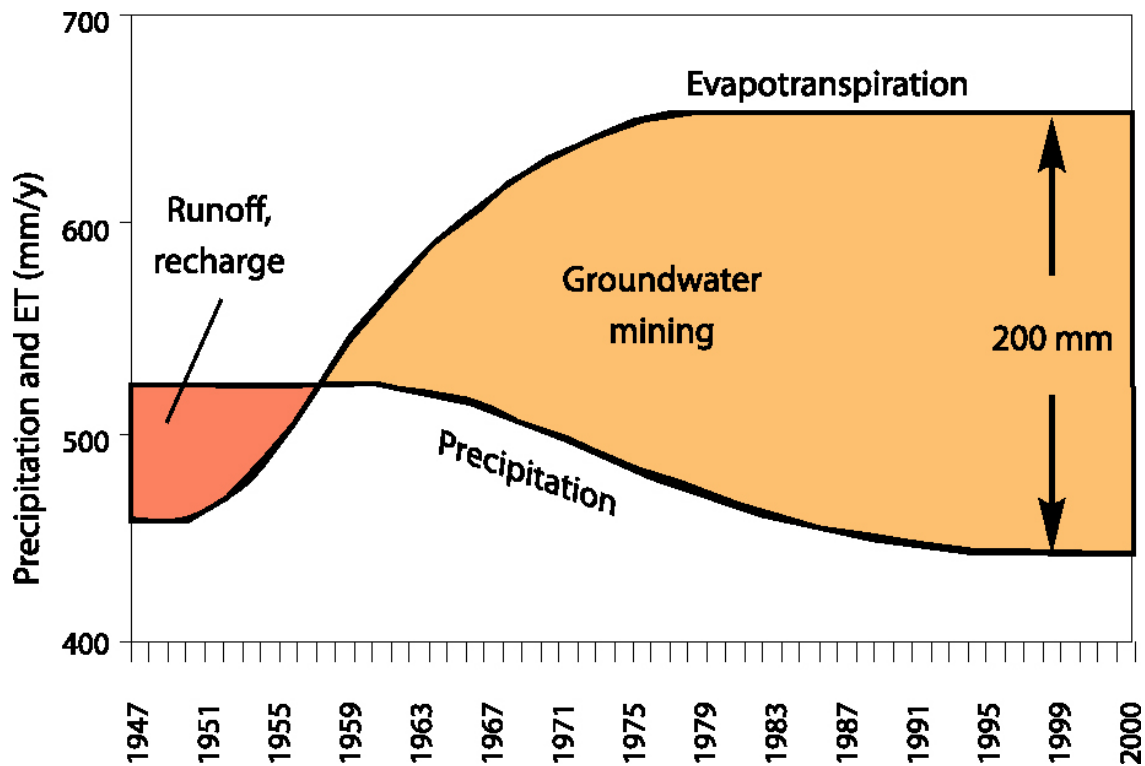
#### *Key Drivers for Degradation Dynamics: The Policy: Water Use Nexus*

IWMI's study used a water balance approach to try and find the answer. It is a simple accounting method used to quantify hydrologic changes. The soil water balance and the groundwater balance in Luancheng County were both studied. The study concluded that the continued decline in groundwater levels is due to the longstanding agricultural policy of achieving food self-sufficiency by continually increasing the irrigated area, coupled with the use of groundwater to supplement precipitation. Even more interesting is what the study reveals about the connection between increasing irrigation efficiency and groundwater levels. In Luancheng County, irrigation efficiency has increased, causing more than a 50 percent decrease in groundwater pumping since the 1970s (fig. 3.5). However, groundwater levels continue to drop steadily. Because excess irrigation water seeps through the soil back to the aquifer underlying irrigated areas and replenishes the water supply, the only significant inflows and outflows to the system are through precipitation and crop evapotranspiration. As long as these two factors remain constant, increased irrigation efficiency will save no water. Instead, other options like reducing the length of the growing season and reducing the extent of irrigated land need to be considered to halt the decline of groundwater levels.

The model shows clearly that simply changing the amount of water applied for irrigation will not affect the rate of groundwater depletion – this leaves only the only two other variables of rainfall and evapotranspiration. With rainfall beyond management control, the only way to reduce groundwater depletion and to achieve real water savings is to address evapotranspiration. This conclusion is further borne out by the relationship between rainfall, evapotranspiration and resulting depletion in groundwater over the study period (figure 3.5).



**Figure 3.5 General Relationships between Precipitation and Evapotranspiration for Cropland in Luancheng Country, 1947-2000**

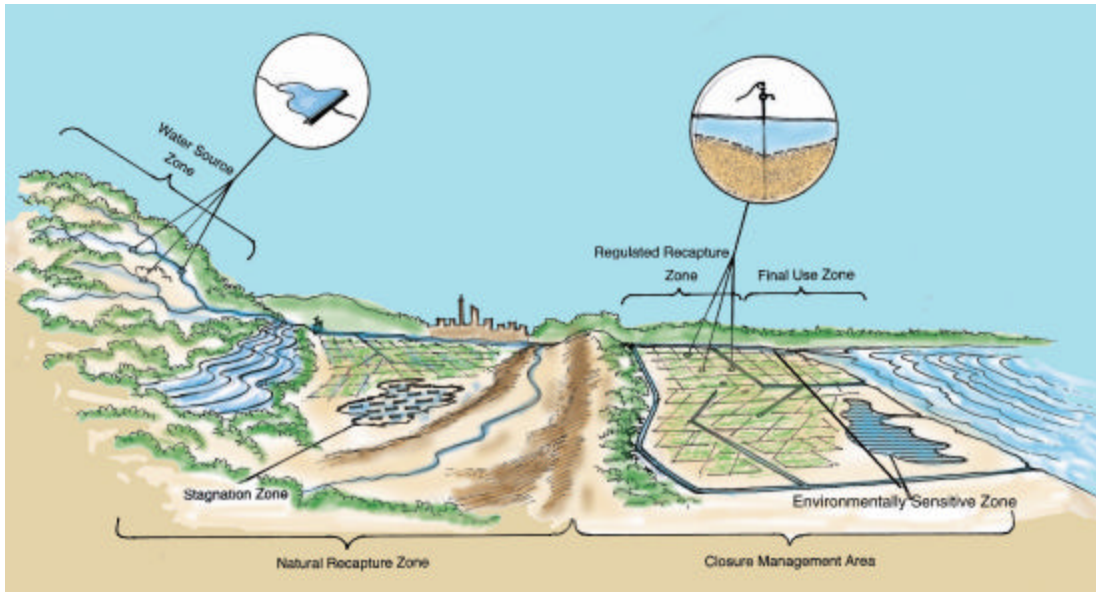


In the early years before irrigation development, precipitation exceeded evapotranspiration and the excess water recharged the aquifer, sometimes causing it to overflow. As irrigated areas grew and the number of crops harvested each year rose, evapotranspiration increased until it exceeded rainfall (See figure 3.5). It was at this point that groundwater mining began and since that time the amount of groundwater mined has been the difference between rainfall and evapotranspiration, irrespective of the amounts pumped out of the aquifer. As long as this difference remains virtually constant, the rate of groundwater depletion too will remain constant.

Taking into consideration the entire hydrologic system, including the soil profile and the underlying aquifer, a simple but nevertheless vital factor that has been overlooked by water policy experts and resource managers over the years—that as long as crop evapotranspiration remains constant or increases there can be no reduction in the rate of groundwater depletion. The answer lies in methods that will either maintain or reduce the rate of evapotranspiration. The holistic study of the hydrologic system points us in the right direction in the search for these solutions.

A concept that is useful in studying hydrologic systems is that of hydronomic zoning. A hydrologic system such as a river basin is divided into hydronomic (Hydro water + nomus management) zones, which are defined primarily according to the destination of the drainage outflow from water uses. Thus, there are zones where water can be reused and those where it cannot, because of location and quality. Expanding this further, each hydrological system can be classified into all or some of the following zones: water source, natural recapture, regulated recapture, stagnation, environmentally sensitive and final use zones (figure 3.6).

**Figure 3.6 Hydronomic Zones in a River Basin**



Source: International Water Management Institute (IWMI)

The classification of the system into the different hydronomic zones (Molden et al. 2001) helps identify the best methods of saving water since each zone has its own best set of water saving measures. In identifying these sets of measures, factors that must be accounted for are the extent to which the system has excess water available for depletion, the level of groundwater dependence, and the extent of pollution and salinity loading.

*Opportunities for Both Water and Land Management: A Selection of Possible Answers*

The most popular and the most politically acceptable way of attempting to save water is increase irrigation efficiency. However, IWMI's study has clearly shown that this will not always be effective. Examining a hydrologic system as a system of hydronomic zones has shown that efficiency technologies will not be effective in natural and regulated recapture zones with groundwater storage and low salt build up. If there is significant salt build up or pollution in a regulated recapture zone, efficiency technologies will be useful in controlling pollution. These methods will also be useful where there is no significant recharge of the aquifer or where the recharge is heavily polluted or to decrease energy use. In a natural recapture zone such as Luancheng County irrigation efficiency will not be effective in stemming groundwater decline. Thus, a variety of other options have been suggested and considered.

A measure that is often suggested for water conservation is water price increases to increase irrigation efficiency. In the case of the Luancheng County this might not be appropriate because in this case, reducing pumping but irrigating the same area will not stop groundwater decline. Rather, what is required is a change in land use; whether this will ensue from higher prices is debatable.

Aside from irrigation efficiency there is a variety of water saving technologies which are put forward as one of the solutions. Some of these technologies may exacerbate the problem if used inappropriately. For example, although sprinkler irrigation will save energy and allow for more precise application of water and fertilizers leading to higher yields, it will not always be effective in

reducing groundwater decline, and in some situations might even aggravate the problem if farmers decide to irrigate more crops with the water they save. Technologies that reduce evaporation such as the use of mulching and the establishment of greenhouses would be ideal for Luancheng County.

Changing the cropping pattern is one possibility, which needs to be carefully looked at. Adopting less water-intensive cropping patterns than the currently predominant winter wheat/summer maize combination is one suggestion. The amount of water saved will depend on the length of the growing season, the root depth and the leaf area. Studies have shown, however, that any cropping routine, which includes a winter wheat cycle, will not show any significant reduction in groundwater depletion. It would appear then that the reintroduction of a winter fallow season is the only way of seeing any significant water savings through crop changes. This, unfortunately, is not an option, which by and large, is likely to be socially and economically palatable.

Another option is the transformation of land use from rural to urban. Although specific data is not available for the Luancheng County, it is commonly accepted that urban land use depletes much less water than crop evapotranspiration. An urban setting would call for a different range of water conservation measures. In the city of Shijiazhuang, overpumping of groundwater has resulted in the deformation of the water table into a funnel shape. This has affected elevations of water levels at different points and has caused directional changes to the natural flow of groundwater. Thus water that would naturally have flowed to the aquifers of Luancheng County is flowing instead to the aquifers of Shijiazhuang City. It is imperative that the net amount of water pumped for the city is reduced if this unsustainable situation is to be reversed.

In an urban setting, precipitation tends to leave the system as runoff, rather than recharging the underlying aquifer, because many of the land surfaces are impermeable. Here, unlike in the study area, efficiency technologies would have a significant effect. A more expensive option is that wastewater is treated and then used to recharge the aquifer. Studies in California have shown that both these measures, though expensive, show better results in terms of water yield-to-cost ratios than agricultural water conservation, land fallowing, and surface storage construction.

With respect to improving urban water use efficiency, industrial facilities provide greater potential savings than do households. Water use per industrial product in China is 3 to 10 times greater than in other industrialized countries. Discouraging water-intensive industries is a measure that has been adopted in some Chinese cities. Likewise there are many different measures that can be considered singly or together in the urban context to provide optimal water use efficiency.

#### *Rationale for Investment*

None of the measures described earlier will be sufficient on their own to solve the problem of groundwater depletion. Thus, an appropriate mix of measures must be identified to achieve optimal water savings and reduced levels of groundwater depletion. Using the kind of thinking underlying the concept of hydronomic zoning, together with a water balance approach, the study in Luancheng County set out to identify the right mixture of solutions. It formulated water saving choices which could be adopted. The sets of options are made up of a combination of changing cropping patterns that leave certain areas of land to lie fallow, and change of land use to urban uses. Each set of options is a different combination of land uses that will deplete no more than 460 mm/yr — bringing the rainfall and evapotranspiration into equilibrium.

#### *Lessons Learned*

- Don't automatically assume that irrigation efficiency improvements save water. Consider the fate of excess irrigation water, and whether or not it replenishes the hydrologic system first.

If excess irrigation water replenishes the hydrologic system, then irrigation efficiency improvement will not save water, and may in fact consume more water by increasing crop production.

- Land and water must be managed conjunctively to achieve sustainable water use. Use a water balance approach to associate each land use with its associated net water depletion to create a sustainable mosaic of land uses.
- For landscape-scale land-use planning, use hydronomic zoning to identify areas where irrigation efficiency improvement would actually improve water management.
- In places where irrigation efficiency improvement does not save water, the only way to reduce the rate of hydrologic depletion (such as water-table declines) is to reduce evapotranspiration. This can be accomplished by reducing the area devoted to cropland (replacing it with less water-consumptive land use) and by reducing the growing season on cropland. Reducing the evaporation component of evapotranspiration, for example, by mulching with plastic can save a smaller amount of water. However, in the North China Plain, the amount of water that potentially can be saved by reducing evaporation is not enough to stabilize declining water tables.
- Don't blindly invest in irrigation efficiency improvements. They are expensive and often are ineffective in saving water at the basin scale. Moreover, downstream water uses and valuable aquatic ecosystems often rely on the "excess" irrigation water that would be "saved."

#### *Investment Needs and Priorities*

- Establish comprehensive worldwide databases of water use, consumption, and availability by basin.
- Research to understand water consumption (depletion) rates for different land uses, especially urban areas, to facilitate conjunctive land- and water-use planning.
- Design and implement urban wastewater treatment to convert final use of hydronomic zones (contaminated by polluted wastewater) into water reuse zones
- Improve urban water-use efficiency and stormwater recharge.
- Locate cities upstream from irrigated agricultural areas, which can reuse treated urban wastewater. (The converse – locating irrigation upstream from cities – is less efficient because crops consume most of the water that they use, whereas cities consume only a small fraction of the water they use.)

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## Web Resources

[www.iwmi.cgiar.org/pubs/rrindex.htm](http://www.iwmi.cgiar.org/pubs/rrindex.htm)

This Note was prepared by Eloise Kendy, The Nature Conservancy.

## Investment Note: Environmental Services Payments and Markets: A Basis for Sustainable Land Resource Management?

### Summary

The concept of payments for environmental services (PES) arises from the recognition that those who protect resources do require compensation for the service they provide to the wider community. One of the most important prerequisites for a functioning PES scheme is an appropriate regulatory framework, establishing property rights and obligations for land use that provide the framework within which environmental services may be negotiated.

A number of PES schemes and pilot programs have been initiated over the past few years, particularly in Latin America and the Caribbean. But experience is inadequate for a thorough comparison of the relative effectiveness of different approaches – and for their replication elsewhere. Transaction costs and the need for government intervention in critical resource areas may prove more expensive than the potential benefits. However, with skilful analysis of experience, PES schemes may be able to overcome some of the limitations of regulatory instruments associated with the creation of incentives for conservation and sustainable use of natural resources, and at the same time stimulate the formation of social capital in those regions where they are established.

PES schemes implemented to date have not been beneficial to the poor: they attract as service providers those who hold title, own larger areas and obtain incomes from sources outside the production unit (thus making land retirement from production represent little in terms of opportunity cost to the landowner). To improve equity requires that schemes restrict or differentiate payments to low income households. PES schemes involving market creation should be linked to a regulatory system that establishes specific limitations on productive activities and that creates the need for those who possess environmental liabilities to negotiate trades with those who exceed the stipulated norms. Without this regulatory framework, there is little hope for creation of markets for environmental services.

### Key Sustainable Land Management Issues

New opportunities for adding value to sustainable rural land resource management are being created in many parts of the world under the rubric of payments for environmental services (PES). Such opportunities arise from the growing perception that to assure nature's services in the long run requires not only that they should be valued by society, but that these values inspire compensation to those who protect resources. As described in box 3.3, natural resource protection and good land use practices generate a gamut of services of both economic and cultural importance, besides assuring functions essential to support and maintain living organisms, including humans.

### Box 3.3: Types of environmental services generated by good land use practices

<i>Water and soil-related services</i>	<i>Climate services</i>	<i>Biodiversity conservation services</i>
<ul style="list-style-type: none"> <li>• Flow regulation;</li> <li>• Quality maintenance;</li> <li>• Aquatic habitat;</li> <li>• Cultural values (recreation, worship);</li> <li>• Control of erosion and sedimentation;</li> <li>• Nutrient cycling;</li> <li>• Reduced salinity</li> </ul>	<ul style="list-style-type: none"> <li>• Microclimate regulation</li> <li>• Reduced emissions from burning;</li> <li>• Carbon sequestration;</li> <li>• Maintenance of terrestrial carbon stocks</li> </ul>	<ul style="list-style-type: none"> <li>• Connectivity and scale for wildlife conservation;</li> <li>• Sustainable use;</li> <li>• Cultural values (recreation, worship, existence value)</li> </ul>

Source: Author's elaboration

### *Lessons Learned*

Experience in a number of countries to date, particularly in the Americas, suggests that creation of environmental services markets and payment schemes is viable and offers opportunities for equitable and efficient provision of public goods. The conditions under which environmental services markets can function best may be enumerated as follows:

1. measurable benefit to the environment from adopting best practices;
2. identifiable sources of services (e.g., improved agricultural practice, new protected areas);
3. regulatory framework establishing limits within which negotiations can occur;
4. services provided contingent on payment (i.e., you shouldn't have to pay for what you would probably receive anyway); and
5. compensation amounts and terms agreed between beneficiaries and providers.

Scientific research can help to identify the origin of services provided and monitor the provision of downstream benefits, relating the latter to the quality of resource protection at the source. However, science has few good tools to arrive at appropriate and equitable values for PES. These must be negotiated between “buyers” and “sellers,” though economic analysis of the willingness of beneficiaries to pay for these services can provide a useful benchmark. In most instances where payment schemes have begun, the “opportunity cost” of income foregone from alternative land uses has served as a yardstick for the maximum that should be paid a property owner to retire land from non-conserving uses. But although this measure is a good indicator of cost to the provider, it may fail to take into account future opportunities for productive land use, and need to be adjusted over time.

One of the most important prerequisites for a functioning PES scheme is an appropriate regulatory framework, establishing property rights and obligations for land use that establish conditions within which environmental services may be negotiated. For example, in some countries such as Brazil, land use codes establish a minimum for the share of private land that must remain under native vegetation in each biome. Many landowners have not complied with this rule, finding it more lucrative to occupy all or a good part of their properties, while others have retained more forest cover than required by law. When government began to enforce this legislation more rigorously, trading was permitted between deficit and surplus forestland owners. This became the germ of a PES scheme, now being tested in various parts of Brazil. In the same light, there would be no space for carbon trading if there were to be no quantitative limits on greenhouse gas emissions.

A number of PES schemes and pilot programs have been initiated over the past few years, particularly in Latin America and the Caribbean. Descriptions of these experiences are summarized in table 3.2.

The first and largest PES scheme to be implemented was Costa Rica's program for environmental service payments. Created at a national scale in 1997, the program by 2005 had been applied to 500,000 hectares of privately owned forests. The program is administered through a national forestry financing fund (FOAFIFO) financed from a combination of sources including a 3.5 percent gasoline levy, electrical utility payments for hydroelectric catchment protection, and grant funds for an “ecomarkets” project from the global environment facility (GEF) (beginning in 2001). In Costa Rica, there is now broad public recognition that intact forests and their environmental services have value. GEF support has ensured greater attention to biodiversity conservation, and to a more equitable

distribution of payments which include women and indigenous communities whose activities promote environmental services (Hartshorn et al. 2005).

**Table 3.2 Incidence of Costs and Benefits for Environmental Services**

<b>Services</b>	<b>Opportunity Costs</b>	<b>Beneficiaries</b>	<b>Payment Mechanisms</b>
Carbon sequestration	Local farmers and landowners (avoiding deforestation)	Global society	Clean Development Mechanism Biocarbon Fund "Non-Kyoto" funds
Watershed protection	Farmers in upper watersheds and catchment areas (foregoing production on fragile lands)	Local downstream communities and enterprises	Water use charges Taxation of water-using enterprises Electric generation royalties
Biodiversity conservation	Local ranchers and farmers and wood producing enterprises (protecting ecosystems)	Global society Traditional peoples	Compensation funds Benefits-sharing for traditional knowledge and germplasm

Source: Author's elaboration

More recently, in 2003, the Mexican government created a national program of payments for water services provided by private forest landowners who agree to protect existing forests, and to restore forest cover on degraded lands. In its first year alone, the program reached over 128,000 hectares in rural communities and *Ejidors* (collective properties) in 15 states. Different from Costa Rica, the Mexican program is financed out of general government revenues rather than from earmarked sources associated with specific environmental service beneficiaries. A GEF-financed project to extend the program and its global benefits, as well as test market-based mechanisms, is in initial stages of implementation (Guillén 2004).

The GEF has also co-financed two programs involving research and PES trials in agricultural and forest management systems, primarily focused on Central America. The first of these is underway in Honduras, El Salvador, Nicaragua, and Belize under the auspices of the Meso-American Biological Corridor and the Program for Sustainable Hillside Agriculture in Central America (PASOLAC). Its objectives are to enable these countries to better adapt to climatic events and water scarcity in prolonged dry seasons, and to assure clean, sufficient, and regular water supplies to communities within this isthmus of globally important biodiversity. PES pilot schemes were initiated in 2002 in six microwatersheds in which municipal governments established funds to finance conservation treatments and modest payments to farmers for improvement in water supplies. The payment scheme led to the adoption of soil and water conservation technologies by farmers that include ceased burning, green manures, terracing, and hedgerows. As a result, water sources are showing signs of recovery. Implementing local pilot actions is perceived to be an effective instrument for developing sound policies at a national level. In El Salvador and Belize, the pilots are intended to provide the basis for structuring national PES programs.

A second pilot program, entitled Integrated Silvopastoral Approaches to Ecosystem Management involves pilot valuation studies and PES payment trials with livestock producers in three sites in Costa Rica, Nicaragua, and Colombia. In these locales, land users agreed under contract to receive annual payments averaging \$500/hectare up to a maximum of \$4,500/property over 4 years based



on incremental provision of biodiversity-related services in their production systems. The payments were to reach a total of 35,000 hectares over the project's cycle. Payments are defined on the basis of a "point" system ascribing weights to different land use attributes insofar as they contribute to biodiversity conservation. As the project evolves, each landowner has the opportunity to increase her payment through implementation of agreed practices (Pagiola et al. 2004).

Finally, in Brazil, government agencies, small farmers' organizations and NGOs have joined forces to create a program for sustainable development of rural family production in the Amazon (PROAMBIENTE). The program began in 2004 in 11 pilot areas in the nine Amazon states, in each of which 500 rural households, primarily land reform beneficiaries, were selected to participate in the scheme. Operationally, PROAMBIENTE combines conventional credit operations with regular monthly payments for farmers equivalent to up to 40 percent of credit. These payments are contingent on compliance with land use criteria based on certified environmental services. Such services include avoided deforestation, carbon sequestration, reestablishment of hydrologic functions, biodiversity conservation, soil protection and reduced risk of fire. The scheme is operating on a pilot basis using general government revenues, and seeking funds from international donors and carbon traders for the environmental services payments

#### *Opportunities for Sustainable Land Management*

It is also necessary to look at the incidence of costs and benefits to devise a workable PES scheme. If changes in land use are proposed as a means to benefit the global environment, through climate change mitigation or biodiversity conservation, the costs should be borne by global society and not by farmers in developing nations. If on the other hand, the majority of benefits are received locally, such as through clean and reliable water supply, these costs should be shared by local water users. In most cases, however, there are cross-benefits: in integrated watershed management, biodiversity may be protected and water supplies assured simultaneously. This provides opportunities for environmental services to be financed jointly by different beneficiaries through the same resource protective activities in a geographical area. This facet makes it logical to create an environmental services fund to receive and disburse contributions from different beneficiaries to finance installation and maintenance of a bundle of land use practices in a given locale. The differential incidence of environmental service benefits and payment mechanisms is described in table 3.2.

Despite their promise, there are a number of perils and pitfalls that can unnecessarily encumber those who seek to set up PES schemes and those that might benefit from them, particularly the rural poor. These difficulties may be summed up in the concept of "transactions costs." The contract negotiations, time and money involved may actually exceed the net benefits of setting up such a scheme, making it seem easier or more cost-effective to adopt land use codes or other regulations than to rely on the magic of the marketplace.

#### *Recommendations for Practitioners*

Experience with the establishment of PES schemes, even in Latin America where they have a longer history, is as yet quite incipient, and therefore inadequate to thoroughly compare the relative effectiveness of different approaches for replication elsewhere.<sup>1</sup> Expectations for PES generally soar but in all likelihood greatly exceed their probable potential to reduce transactions costs and the need for government intervention in critical resource areas. However, PES schemes may be able to overcome some of the limitations of regulatory instruments associated with the creation of incentives for conservation and sustainable use of natural resources, and at the same time stimulate the

formation of social capital in those regions where they are established. The following principal lessons have been learned from these experiences to date, focused primarily on watershed services.

Calculating the value of benefits arising from specific land use practices is a gray area subject to great uncertainties. PES schemes will be more effective, for example, if they are directed at water quality than at water supply associated with forest cover enhancement, because there are a number of ways in which conventional wisdom and scientific proof diverge regarding the water flow regulation functions of forests.

At the outset of program design, it is best to begin with services for which there is a clear established demand (e.g., improvement in water quality associated with discharge of animal residues), and for which it is relatively easy to prove a relationship between the change in practices and the condition of ambient water quality supplied.

The best “bang for the buck” is obtained by promoting practices that offer multiple benefits, such as restoration of streambank vegetation, that can simultaneously reduce sedimentation of water courses, sequester carbon and reestablish biological connectivity between forest fragments.

Rather than invest in complicated procedures to calculate environmental benefits, PES should be estimated initially on the basis of opportunity costs associated with adoption in comparison with a baseline scenario (e.g., the net income foregone from land retired from production to permit regeneration). It is not always necessary to cover the full opportunity costs of such practices to attract an adequate number of service providers.

In general, PES schemes implemented to date have not been beneficial to the poor. They attract service providers who hold titles, own larger areas, and obtain incomes from sources outside the production unit (thus making land retirement from production represent little in terms of opportunity cost to the landowner). To improve equity requires that schemes restrict or differentiate payments to low-income households.

PES schemes involving market creation should be linked to a regulatory system that establishes specific limitations on productive activities. That creates the need for those who possess environmental liabilities to negotiate trades with those who exceed the stipulated norms. Without this regulatory framework, there is little hope for creation of markets for environmental services.

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## **Web Resources**

Flows – News on payments for watershed services. Subscribe or download regular bulletins at <http://www.flowsonline.net/>

## **ENDNOTE**

1. See Waage et al. (2006) for an assessment of capacity-building opportunities for dissemination of PeS approaches worldwide.

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## **Innovative Activity Profile: Species Diversity in Fallow Lands of Southern Cameroon -- Implications for Management of Man-Made Landscapes**

### *Summary*

Humid tropical forests provide a range of products and services. Fallow cycles are considered the most common source of deforestation in southern Cameroon and are attributed to smallholder agriculture. As fallow periods become shorter, fallow composition changes; ultimately endangering the succession process of the natural forest.

Fallow lands of less than 10 years old form an important component of the agricultural landscape in the humid forest zone of southern Cameroon. These fallow types have been shown to be an essential part of local livelihoods, as they are used not only for cropping, but also as key reserves of non-timber forest products. There are good reasons to focus on the development of sustainable fallow shifting cultivation systems which may be more environmentally acceptable than permanent farming systems in terms of deforestation, soil erosion and carbon storage.

### *Introduction*

There are two major environmental concerns facing policymakers and stakeholders concerned with the humid forests of Cameroon: (a) deforestation and (b) forest degradation. Humid tropical forests provide a range of products and services, that include: timber and non-timber forest products, use of forest biomass as a fertility input (when converted to ash through slash-and-burn techniques), the conservation of important biodiversity, the protection of soil resources and watersheds, the prevention of desertification, and the regulation of local and global climatic patterns through carbon sequestration. Fallow cycles are considered the most common source of deforestation in southern Cameroon and are attributed to smallholder agriculture (Gockowski and Essama-Nssah 2000). As population pressures increase and fallow periods become shorter, fallow composition changes; ultimately endangering the succession process of the natural forest.

Most studies on shifting cultivation have been based on the assumption that species diversity declines when the length of fallow periods is reduced. This theoretical presentation of the essence of ecological dynamics in shifting cultivation has been adopted by a wide range of authors (e.g., Ruthenberg 1980; Sanchez 1976). This theory has partly been responsible for fuelling the condemnation of fallowing by many governments as it clearly shows that when fallow periods are shortened because of land scarcity and population pressure or other factors, development of this farming system will in all cases find itself in a downward spiral of low species diversity and declining yield in the subsequent cropping seasons.

Fallow lands of less than 10 years old form an important component of the agricultural landscape in the humid forest zone of southern Cameroon. These fallow types have been shown to be an essential part of local livelihoods, as they are used not only for cropping, but also as key reserves of non-timber forest products. However, one of the consequences of increasing resource use pressure and subsequent shortening of fallow duration is the invasion of these land use systems by the Asteraceous species *Chromolaena odorata* (L.) (Ngobo et al. 2004; Weise 1995; Weise and Tchamou 1999).

*Chromolaena* is widely regarded as a serious threat to agriculture in West Africa, and is rapidly spreading throughout Southeast Asia into the south Pacific and into central and eastern Africa from the infestations in West and South Africa. Moreover, shorter fallow periods are believed to cause environmental damage in the form of soil mining and accelerated erosion. This, in combination with

national interests in protecting forest resources for other purposes, has in many cases led to an official resentment toward fallowing practices; making it difficult to focus on the development of sustainable fallow shifting cultivation which may be more environmentally acceptable than permanent farming systems in terms of deforestation, soil erosion, and carbon storage.

The reported resource use intensification in the study area and the increasingly acknowledged need for more productive and environmentally friendly agricultural systems for local resource-poor farmers have stimulated renewed interest in the mechanisms by which, among other functions, fallows restore ecosystem fertility and biodiversity. Concern for more profitable and ecologically sustainable fallow systems provided impetus for initial research, particularly given the reported increasing abundance of fallows of shortened duration in the humid forest zone of Cameroon. A lack of reliable information regarding the characteristics of these land use systems in the humid forest zone of southern Cameroon has hindered resource managers' attempts to develop adapted strategies.

#### *Description of Forest Fallow Management Innovation*

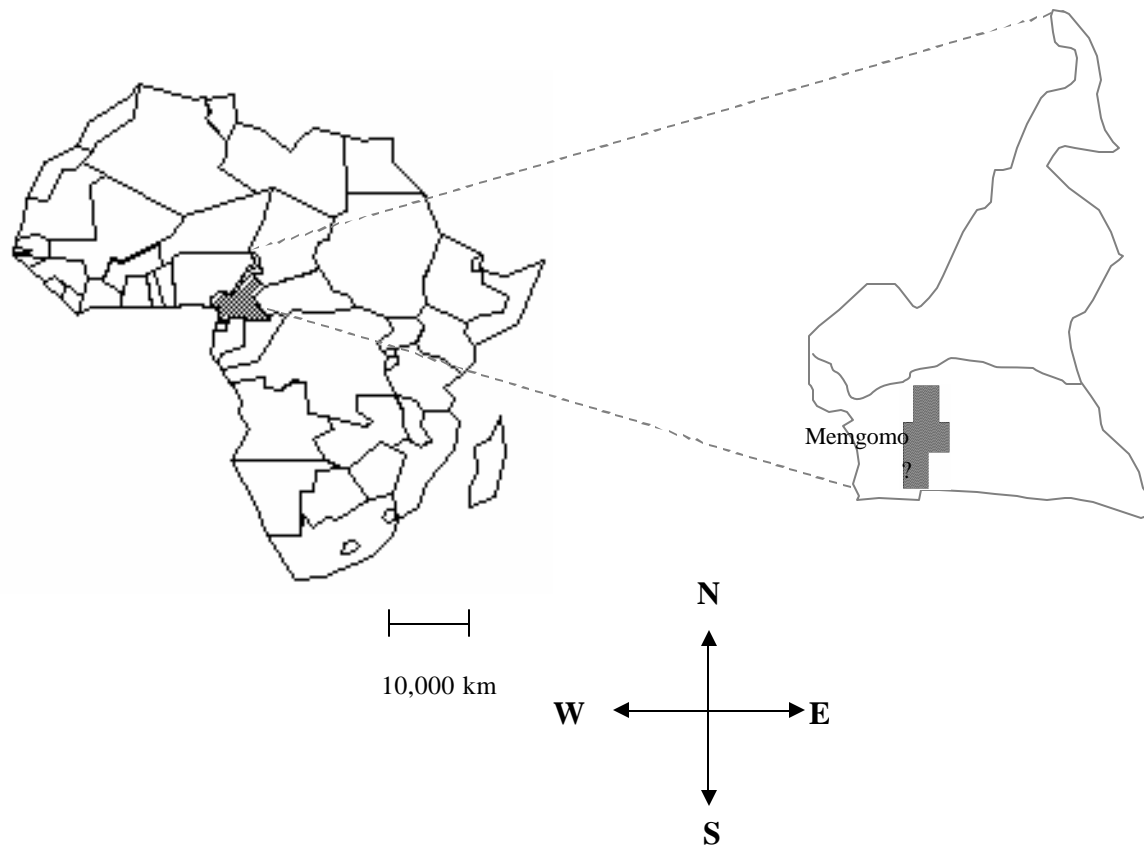
The activity reported here underlines the need to distinguish forest fallows dominated by *Chromolaena* from fallow types that have recently been a forest when designing strategies and policies for sustainable management of short fallows in the humid forest zone of southern Cameroon. The low frequency of forest species recorded in frequently cropped fallows emphasizes the urgent need to develop vegetation management strategies that should aim at accelerating plant succession during the fallow phase. The information and knowledge that is presented, is specific to the Mengomo, located in the southern part of the humid forest zone of Cameroon, (figure 3.7), it is relevant for similar humid forest sites in Africa.

The major site where the information for this note was derived is situated at 2°20'N and 11°03'E, Mengomo is a small locality (598 inhabitants and 83 households) that lies 52 kilometres south of the city of Ebolowa. It is characterized by a hot and moist equatorial climate, with a minimum mean annual temperature of about 20°C and a maximum of 29°C (National Meteorological Station of Yaoundé, mean of 11 years: 1983-1994 in Santoir and Bopda, 1995). The mean annual rainfall is ca. 1800 mm, falling in a bimodal pattern, which determines two rainy seasons (March-July and August-November) and two drier seasons (July-August and November-March) of unequal duration. The main natural vegetation is a mosaic of semi-deciduous tropical forest, fallow fields of various length and vegetation (Letouzey 1968). The farming system is one of the lowest intensified among villages of the area, and production is highly oriented toward auto-subsistence. The site is characterized by yellow ferralitic and highly desaturated soils that fall into the FAO class of Orthic Ferrasols (Koutika et al. 2000).

#### *Impacts on vegetation community and biodiversity*

Both species and functional diversity were significantly associated with vegetation structure and plant community composition in 5-7 years old fallows under different land use intensity regimes. Recently forested fallow types displayed the highest values of stand structural parameters, except for the site disturbance index. There was no significant effect of fallow type on the mean basal area or crown cover.

**Figure 3.7 Study Area located in the Humid Forest Zone of Southern Cameroon**



Source: Author elaboration.

A total of 224-225 species of vascular plants were recorded in the study sites, belonging to 72-74 families. The most richly represented families were Euphorbiaceae, Fabaceae (or Papilionaceae), and Sterculiaceae, respectively; with 23, 21, and 12 genera. Although up to 85 plant species were common to all fallow types, about 67 plants were exclusive to stands that had been forests prior to the previous cropping cycle (table 3.3). Among the species most frequently found in all study sites were *Chromolaena*, *Haumania danckelmaniana* Milne-Redh., *Milletia* spp., *Dioscorea* spp., *Cissus* spp., *Cnestis ferruginea* DC, and *Nephrolepis biserrata* (Sw.) Schott, which were present in more than 70 percent of the sites.

Frequently cropped fallows were characterized by the abundance of *Chromolaena*, *Albyzia zygia* Macbride, and *Dioscorea* spp, with the under-storey characterized by a few Poaceae and some Cyperaceae. The vegetation in moderately cropped fallows was consistently least diverse (58-132 species). Although *Chromolaena* was still abundant, this fallow type was characterized by the importance of Commelinaceae and Marantaceae species, represented by different species of *Palisota* and *Megaphrynium*. There was more under-storey than in the previous fallow type, and it comprised some forest herbaceous species like *Aframomum* spp., *Harungana madagascariensis*, and *Haumania danckelmaniana*. A high number of species (150-171) was recorded in recently forested fallows. The vegetation in fallow sites of this type was clearly stratified in three distinguishable layers: (a) an upper storey dominated by pioneer semi-woody species (of up to 6-8 m height), (b) an intermediate stratum

that comprised small individuals of mostly secondary or primary forest species, and (c) a lower storey dominated by secondary forest herbaceous species. Characteristic species of the mature secondary forest were consistently present in this fallow type.

**Table 3.3 Total Number of Plant Species Recorded in Three Fallow Types in the Humid Forest Zone of Southern Cameroon.**

<b>Plant community composition</b>	<b>Frequently cropped</b>	<b>Moderately cropped</b>	<b>Recently forested lands</b>	<b>Total fallows</b>
Total species	111-165	58-132	150-171	224-225
Species with frequency of presence $\geq 70\%$	12	13	17	7
Species with frequency of presence $\geq 50\%$	26	33	47	27
Total families	54	37	64	72-74
Families with one species	31	25	33	34
Species exclusive to fallow type	4	33	34	-

Source: Authors elaboration

*Patterns of variation in species composition among fallow types.* Ordination analyses showed a clear pattern of distribution of species along a gradient of resource use intensity. Except for mean litter depth, a significant positive correlation was found between plant biodiversity (as indicated by the number of species and other diversity indices) and fallow structural features. Conversely, there was a negative significant correlation between plant species diversity and crown cover of woody plants as well as site disturbance index. The influence of vegetation composition and vegetation structure on species assemblages reported in this study, highly correlated with litter depth and basal area, suggest that there is a gradient of soil organic matter content and soil moisture from the less to the more intensively farmed fallow types.

#### *Lessons Learned*

The results of this study suggest that increasing land use intensity (reflected here by increasing number of fallow-cultivation cycles) will initially have little effect on the species diversity of the shortened fallow plant community. However, as the link to the forest is reduced, altering the site vegetation structural characteristics and decreasing shade (leading to a more homogeneous microclimate), there will be an adverse effect and the species richness will decline. Nevertheless, other studies have shown that increasing land use intensity results in the loss of some uncommon useful species of shortened fallow systems such as *Megaphrynium* spp., *Sarcophrynium* spp. (Aweto 2001; van Dijk 1999). As in this study, there may be no replacement with uncommon weed species because they are being exposed to competition from ubiquitous species through habitat disturbance.

In Cameroon, smallholder agriculture is held to be the major source of deforestation. Therefore, any proposed multi-sectoral approach for addressing deforestation must start with agriculture. A summary of the lessons and challenges while designing sustainable vegetation management strategies for the humid forest area of southern Cameroon are listed below:

- There are sustainable pathways for rural development in the humid forest zones that can minimize the damage and, in some cases, even improve the environmental services of the

cultivation/forest mosaic ecosystem. The productivity of fallow lands need to be assessed in order to evaluate their sustainability and economic viability for local resource-poor farmers.

- Measures to achieve these goals: (a) focus on the collection and dissemination of relevant and reliable information, (b) work with a larger set of stakeholders, and (c) use Cameroonian expertise to gain local perspective and build capacity.
- Given the global importance of 5-10 years fallows in the humid forest zone of southern Cameroon, and the considerable variation in published estimates of plant species diversity and change; it is imperative that a reliable and indisputable monitoring mechanism be developed. The rapid evolution in remote sensing technologies offers the best potential for quantifying patterns of change. Reliable and replicable estimates from such techniques would be of great use to policy makers and other stakeholders.
- It is, therefore, necessary to develop improved systematic data gathering so as to update understanding on the contributions of fallows (and shortened fallows, in particular) to household, community, and national livelihood strategies. This will be of great use to policy makers and development organizations in developing 'improved' and sustainable fallow systems that may benefit both small-scale farmers and the environment.



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## **Innovative Activity Profile: Domestication and Commercialization of Forest Tree Crops in the Tropics**

### *Summary*

The harvesting of indigenous fruit trees (IFTs) represents an important food supplement and cash income for rural people in many tropical countries. Although most of the fruits from IFTs are still being harvested from the wild, and traditional crops and fruits play a valuable role in supporting household food security, this last role could be significantly enhanced if improved varieties and production, harvesting, and storage techniques could be made available to the rural poor. Thus a pro-poor strategy involves moving away from just depending on wild harvesting.

Participatory domestication is defined as genetic improvement that includes farmer-researcher collaboration, and is farmer-led and market-driven. It was devised to overcome the shortcomings of earlier top down approaches of conventional breeding and forestry. It leads to consideration of the wider context in which it is possible to identify which traditional crops and fruits are becoming marginalised, how much diversity occurs within them, their productive and genetic potentials, post-harvest requirements and their processing and marketing potentials. These efforts involve plant taxonomists, ethno-botanists, crop breeders, crop scientists, food scientists, agricultural engineers, human nutritionists and economists and are conducted in conjunction with farmer associations and commercial establishments.

### *Introduction*

The harvesting of indigenous fruit trees (IFTs) from the wild predated settled agriculture represents an important food supplement and cash income for rural people in many tropical countries. Evidence is accumulating that IFTs can contribute significantly to household income in every region in the tropics (Akinnifesi et al. 2007; Leakey et al. 2005), and is a major opportunity for asset-building for smallholder farmers. Take, for example, Southern and Eastern Africa. Start with the fact that most of the food crops grown by East and Southern Africa's small-scale farmers did not originate from Africa. Maize, beans, groundnuts, sweet potato and cassava are all exotics from tropical America and have largely displaced the sorghum, millets, cowpea and yams produced by yesteryear's traditional farmers. Marginalising African crops has resulted in collapsed traditional seed systems, reduced farm biodiversity, poorer diets, decreased food security, and declining cultural tradition. Ironically, today the demand for traditional foods by urban consumers is increasing because indigenous small grains, pulses, fruits and leafy green vegetables are both tasty and nutritious. But often these foods are not readily available. In addition, in times of food scarcity, these traditional crops and fruits play a valuable role in supporting household food security. This role could be significantly enhanced if improved varieties and production, harvesting, and storage techniques could be made available to the rural poor.

A large amount of knowledge on the opportunities, challenges, knowledge gaps, and constraints of indigenous fruit trees has been gathered in the past few years. There is continued enthusiasm among researchers and development practitioners (especially in the past two decades) to explore the opportunities to meet the food needs of humanity through IFTs. As a result, there is an increasing emphasis on tree domestication strategies (promoting IFTs with economic potential as new cash crops), product development, and commercialization and marketing of agroforestry tree products (AFTPs). This brief provides a highlight on the opportunities, achievements and challenges of indigenous fruit trees domestication, utilization and marketing in Africa, Latin America, and Asia.

### *Description of tree domestication innovation*

Participatory domestication is defined as genetic improvement that includes farmer-researcher collaboration, and is farmer-led and market-driven. It was devised to overcome the shortcomings of earlier top down approaches of conventional breeding and forestry. Participatory domestication approaches have been applied by ICRAF in, *U. kirkiana*, *Sclerocarya birrea* and *S. cocculoides* in southern Africa (Akinnifesi et al, 2006), while West Africa for *Dacryodes edulis* and *Irvingia gabonensis* are the focus in West Africa (Tchoundjeu et al, 2006). In Latin America, *Bactris gasipaes* Kunth and cupuaçu (*Theobroma grandis*) have been subjected to domestication especially Brazil and Peru (Clement et al, 2007). The objectives of the domestication projects led by the World Agroforestry Centre are (i) to identify technically, economically and socially viable investment opportunities for indigenous fruit domestication in the context of sustainable land management; (ii) to establish pilot projects which meet pre-established investment criteria.

The domestication research started with identifying species preference depending on the extent they are able to meet the subsistence and cash income needs of the producers and market participants. The seven-step principles and application of priority setting was detailed by Franzel et al (1996) and tested in the regions. Results of the priority setting across regions are presented in Table 1.

Detailed principles and strategies for participatory domestication based on clonal selection and vegetative propagation has been described by Leakey and Akinnifesi (2007). This has had significant benefits – for example, the long juvenile phase (period before first fruiting) has been reduced from 10-15 years to 3-4 years for *D. edulis* in West Africa, and *U. kirkiana* in Southern Africa and cupuaçu (*T. grandifolia*) in Latin America.

### *Benefits of activity and its implications for sustainable land management*

The IFT species mentioned above are important in many ecosystems, and farmers make efforts to conserve and cultivate them on the farmlands. Five factors are important in cultivation and sustainable management of IFTs on the landscapes: site requirements, genetic variability and improvement potential, propagation methods, nutritional properties and commercial potential (Jama et al, 2007). Knowledge is important for tree management and sustained land management. Akinnifesi et al (2007) provide insights into the potential of integrating IFTs cultivation into smallholder production in ways that contribute to livelihoods, biodiversity conservation and sustainable land productivity.

Trees can contribute to improved organic matter accumulation, erosion control and nutrient recycling from deeper soil layers. In a farming system that includes income from tree crops, the farmer can use some of the returns from fruits to invest in fertilizers, seeds and other inputs in other parts of the system.

### *Lessons learned and issues for scaling up tree domestication*

Although most of the fruits from IFTs are still being harvested from the wild, and traditional crops and fruits play a valuable role in supporting household food security, this last role could be significantly enhanced if improved varieties and production, harvesting, and storage techniques could be made available to the rural poor. Thus a pro-poor strategy involves moving away from just depending on wild harvesting; domestication research and development have progressed significantly, especially in Africa and Latin America for indigenous fruit trees. Efforts to prioritize select and cultivate superior cultivars of indigenous fruit trees using participatory approaches are noted across the regions. Such strategies generally involved, i) application of farmer-centred, market-led approaches involving careful participatory selection of the right species and elite cultivars to be

promoted, and the development of low-cost simple propagation techniques, establishment and management practice in cooperation with farmers; ii) post-harvest handling, product development and prospecting of IFTs products and; iii) market research, enterprise development and commercialization. The overall objective is to identify, conserve, improve and promote traditional crops and fruits as a means of improving their seed systems and markets, making the crops more attractive to small-scale farmers – with specific aims to:

- better understand which traditional foods are becoming marginalised and explore avenues for their revitalisation.
- explore opportunities for processing traditional foods in ways that make them more attractive and easily prepared by urban consumers, thereby strengthening their demand and markets.

This leads to consideration of the wider context in which it is possible to identify which traditional crops and fruits are becoming marginalised, how much diversity occurs within them, their productive and genetic potentials, post-harvest requirements and their processing and marketing potentials. These efforts involve plant taxonomists, ethno-botanists, crop breeders, crop scientists, food scientists, agricultural engineers, human nutritionists and economists and are conducted in conjunction with farmer associations and commercial establishments.

A summary of the lessons and challenges are listed below:

- The investment needs for wider cultivation and scaling up of tree domestication of indigenous fruit trees include: (a) quality planting material in sufficient quantity, (b) adequate skills and resources for village-level nurseries in decentralized systems, and (c) facilities for micropropagation and tissue culture centers for rapid multiplication of specialized propagules (Akinnifesi et al. 2006).
- Measures to speed up the multiplication of improved planting materials are necessary. These include the application of biotechnology and tissue culture techniques in germplasm multiplication and delivery deserves greater attention.
- Research and development on the domestication of IFTs has advanced only in a few species such as, *Uapaca kirkiana*, *Sclerocarya birrea*, *Parinari curatellifolia* in southern Africa, *Dacryodes edules*, *Irvingia gabonensis* in West Africa, *Theobroma grandifolia* and Peach palm (*Bactris gasipaes*) in Latin America. There is a need to expand the range of IFTs currently being researched in different regions of the tropics.
- Droughts and climate affect fruiting potentials, cycles and seasonal variability, and cause major reduction in fruit production and quality. It is important to investigate how tree planting affects climate change on one hand and, how trees are (can be) affected by climate change. This will ensure that sufficient resilience is built in tree domestication efforts.
- Farmers and researchers have complimentary knowledge and knowledge-deficiencies, so that integrating this knowledge from both parties through participatory processes has been shown to speed up technology adoption and performance.
- There are comparatively few studies that provide conclusive evidence on the profitability and payback periods of IFTs cultivation or wild collection. Smallholder farmers may need initial incentives or credit lines for tree establishment, management, and value addition.

- Adoption of tree-based practices such as IFTs is more complex than those of conventional crops because of the multi-year cycles required for testing, modification, and eventual “adoption” by farmers. There is need to understand the key factors that drive adoption of improved IFTs and their impacts at multi-scales, (i.e., household and landscape levels). These studies will provide insights into the level of technology change that would stimulate adoption and impact of IFTs. Such studies are important to guide investment, adoption, and policy decisions regarding IFTs.
- As the technology development processes become complex, the uptake of the technologies by farmers will remain low. The development and dissemination of IFT systems must continue to emphasize practices that require little capital and simple methods of scaling up improved processes and techniques to wider communities. Such low-cost techniques include small-scale nursery operations, vegetative propagation, use of organic manures and tree management.
- For market-led IFT initiatives, the market attribute of IFTs products must be unique or substantial enough and should be comparable or superior to conventional product sources to make a dent in the market. For instance, camu-camu (*Myrciaria dubia*) is being promoted in Latin America for its extremely high vitamin C content in its pulp (2.8-6.0 g of ascorbic acid per 100g)--this is 30 times as high as the equivalent weight of orange.
- Second generation issues such as the potential occurrence of new pests following the introduction of new trees must be carefully investigated as IFTs are domesticated and improved germplasm are selected.
- There is a need for improved systematic data gathering to update global knowledge on the contributions of IFTs to household, community, and national income and livelihood strategies. This will enhance the opportunities by policy makers and development organizations in using IFTs as a potential intervention strategy for reducing poverty.
- There is need for innovative research and development efforts on IFTs to help bring about improvements in cultivation, scaling up, markets, and small-scale enterprises in the tropics. The improved performance of market of AFTPs would stimulate growth in the rural economy.
- Adoption of agroforestry is not a simple direct relationship of only technological characteristics; it is a matrix of several groups of factors that include: household and community level factors, institutions, and the socioeconomic constraints and incentives that farmers face. As a result, rather than technology change alone, it is recommended that the development of IFTs should put balanced emphasis on the economics, the people, and the institutional and policy context under which farmers operate.

#### *Investment Needs, Priorities, and Scaling Up*

One of the most effective ways of achieving scaling up of IFTs cultivation is to involve farmers in the entire process of participatory selection, propagation, nursery and tree establishment, and management of superior planting materials. This will dramatically shorten the time required to produce and disseminate planting materials from centralized nurseries to farmers. It is important to provide farmers with high-quality germplasm and make it available in a timely manner. Farmers can be organized to produce high-quality seed, seedlings, and vegetative propagule as evidenced in small-scale nursery enterprise managed by farmer groups, as done in West and southern Africa and in Peru.

Contribution of IFTs in terms of valuing their contribution to the national economy is long overdue, and there is need to devote investment resources for their development. Only very few cases of

active promotion of IFTs has been documented in the tropics. There is need for fostering cross-collaboration and knowledge exchange among regions where species are cultivated, used, and or traded; develop indicators and tools for assessing impacts and increase investments on priority indigenous fruit trees.

#### *Policy Considerations*

Key policy priorities emerging from the general literature on relationship and development of IFTs are as follows:

- One way IFTs could be scaled up and mainstreamed into the government thinking is to engage in a pro-active increase in awareness creation and raising the profile of the contributions of IFTs in policy debates and development intervention programs. This will require a long-term investment and an appraisal of policies governing land and tree tenure in many countries in the tropics to reduce institutional constraints to tree planting and enact policies that facilitate cross-border trades and harmonization of exploitation, transportation, and germplasm exchange.
- There is a need to formulate regulations that will ensure that IFTs exploitation, processing, commercialization, and on-farm cultivation does not pose a threat to their conservation. These imply that they be treated as cultivated crops instead of intangible forest products from the wild.
- Enacting policies to ensure that intellectual property rights of farmers such as: farmer breeders, community custodians, and the farmer breeder's right of researchers are well protected. This will ensure that benefits from IFTs domestication are not exploited by large-scale commercial growers. Adoption of the International Union for the Protection of New Plant Varieties (UPOV) by governments in the tropics is suggested.

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## Web Resources

[www.worldagroforestrycentre.org](http://www.worldagroforestrycentre.org)

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## **Innovative Activity Profile: Avoided Deforestation with Sustainable Benefits - Reducing Carbon Emissions from Deforestation and Land Degradation**

### *Summary*

While the Clean Development Mechanism (CDM) of the Kyoto Protocol makes some allowance for afforestation and reforestation, it has so far excluded 'avoided deforestation' for good reasons. However, the global climate change community is increasingly recognizing that it must address the challenge of reducing emissions from deforestation and degradation (REDD). Besides the obvious magnitude of the potential for REDD to reduce climate change, the current situation is creating perverse incentives and disincentives affecting other dimensions of climate change mitigation. The current IPCC Good Practice Guidelines for National Greenhouse Gas Inventory provide a coherent framework for dealing with aboveground as well as belowground carbon impacts of Agriculture, Forestry and Other Land Use (AFOLU).

According to expert opinion in the IPCC community that is responsible for the guidelines, however, the net emission estimates from land use and land cover change may carry an unacceptably high uncertainty margin of as much as 60 percent. Data and methods available in national and international research networks can be analyzed to improve the accuracy of estimates, derive better estimates of the uncertainty, and identify ways to reduce it. An effective mechanism for reducing carbon emissions through avoided deforestation would have related, but separate, mechanisms at the international and national levels. Between countries, political negotiations should be convened to establish commitments to baseline and target emission levels. Countries that attain superior performance in avoided carbon emissions through avoided emissions should be eligible for carbon offset payments or credits through multi-lateral or bilateral arrangements.

The current 'avoided deforestation' debate offers a chance to correct some of the major inconsistencies in the current system of carbon trading. Some of the key constraints that need to be overcome relate to scale, scope, political commitment, technical procedures and data quality. Best practice is emerging on the types of national and local mechanisms that countries can apply with much lower transaction costs than current CDM projects. Avoided deforestation with sustainable benefits can generate both local and global benefits. Research by the ASB partnership and others shows that intermediate land uses can store significant quantities of carbon, maintain flows of ecosystem services, generate good economic returns and reduce pressure on remaining.

### *Project Objective and Description*

Climate Change and its global impacts can no longer be ignored. While cutting emissions from fossil fuel consumption obviously deserves continued attention by all levels of the global society, the approximately 20 percent of emissions that are due to loss of forests and peatlands cannot remain outside the purview of climate change mechanisms. Recognizing this, the Conference of the Parties to the UN Framework Convention on Climate Change invited a discussion "on issues relating to reducing emissions from deforestation in developing countries, focusing on relevant scientific, technical and methodological issues, and the exchange of relevant information and experiences, including policy approaches and positive incentives" in its eleventh session on agenda item 6 (FCCC/CP/2005/L.2).

The World Agroforestry Centre (also known as the International Centre for Research in Agroforestry – ICRAF) prepared a submission for consideration in the discussion. The submission is



based on extensive research across the humid tropics by a consortium of international and national organizations operating within the ASB Partnership<sup>1</sup> for the Tropical Forest Margins (ASB), with key research results generated by Brazil, Peru, Cameroon, Thailand, Indonesia and the Philippines. This IAP summarizes the case for 'avoided deforestation' with sustainable benefits as a simple way to reduce carbon emissions from deforestation and degradation.

*Presentation of Innovation: The ASB Alternative*

Several years ago the international science community established that about 20 percent of global CO<sub>2</sub> emissions are generated through land use change and the conversion and degradation of forests. While the Clean Development Mechanism (CDM) of the Kyoto Protocol makes some allowance for afforestation and reforestation, it has so far excluded avoided deforestation. There are good reasons for this:

- The definition of what is and is not a 'forest' is ambiguous.
- The CDM has taken a project approach. Re-forestation deals with enhancing tree cover on degraded lands, where it is easier to monitor carbon stocks and attribute changes to project activities.
- The CDM mechanism pays great attention to 'leakage' (making sure that gains in one place do not cause losses in another place) and 'additionality' (ensuring that carbon gained and/or conserved, relative to baselines, would not have occurred without the project) - issues that cannot be reasonably addressed in avoided deforestation projects with limited geographical scope.
- The complexity of rules for applying the Clean Development Mechanism to afforestation and reforestation has meant that many of the potential benefits have been offset by the costs of consultants, research organizations, and government agencies. Little carbon value has reached local beneficiaries. In the more difficult case of avoided deforestation, the benefits are even more uncertain.
- The National Guidelines for Greenhouse Gas inventories (IPCC) (modified 1996 and 2006) indicate net emission estimates from land use and land cover change may carry an uncertainty margin of as much as 60 percent. This makes it very difficult to come to a valid estimate of the contribution to global CO<sub>2</sub> of land use changes and is the largest uncertainty in quantification of greenhouse gas (GHG) inventories.
- Much deforestation is actually planned by land managers and governments because it leads to land uses with higher economic returns. Completely avoiding deforestation would require offset payments that are not feasible under present circumstances. Negotiating intermediate targets for "partial deforestation" of a particular landscape would be very complex.

Despite the difficulties, however, the global climate change community is increasingly recognizing that it must address the challenge of reducing emissions from deforestation and degradation (REDD). Besides the obvious magnitude of the potential for REDD to reduce climate change, the

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<sup>1</sup> The Alternatives to Slash and Burn (ASB) program comprises a well-established global alliance of over 80 local, national and international partners dedicated to action-oriented integrated natural resource management (iNRM) research in the tropical forest margins. It is the only global partnership devoted entirely to research on the tropical forest margins. ASB's goal is to raise productivity and income of rural households in the humid tropics without increasing deforestation or undermining essential environmental services. ASB applies an integrated natural resource management (iNRM) approach to analysis and action through long-term engagement with local communities and policymakers at various levels.

current situation is creating perverse incentives and disincentives affecting other dimensions of climate change mitigation. For example, an Annex – I country that imports biofuels from non-Annex I countries to meet its Kyoto targets is not accountable for forest conversion that biofuel production might cause. Further, public and political willingness to contribute to the control of GHGs through relatively small reductions elsewhere will erode if large and avoidable emissions are left out of scrutiny. Non-participation by the United States and Australia create similar problems for the Kyoto protocol.

The current IPCC Good Practice Guidelines for National Greenhouse Gas Inventory provide a coherent framework for dealing with aboveground as well as belowground carbon impacts of Agriculture, Forestry and Other Land Use (AFOLU). The IPCC framework could become the primary framework for reporting and accountability in non-Annex I countries, aligned with the rules that currently apply to Annex-I countries.

According to expert opinion in the IPCC community that is responsible for the guidelines, however, the net emission estimates from land use and land cover change may carry an uncertainty margin of as much as 60 percent. In time, the use of the IPCC guidelines over multiple measurement periods will reduce this margin, as annual updates provide better information on which to base future estimates. But the current uncertainty margin of 60 percent is clearly unacceptably high. The opportunity to participate in a market for reduced AFOLU carbon emissions would generate clear incentives to improve the accuracy of the accounts.

Data and methods available in national and international research networks can be analyzed to improve the accuracy of estimates, derive better estimates of the uncertainty, and identify ways to reduce it. The two components of uncertainty are interlinked: the classification of land cover and land cover change is unsatisfactory, and there is too much uncertainty regarding the mean carbon stocks per unit area in each land cover class. It is clear that the binary classification (e.g. with just 'forest' and 'non-forest' as classes) is insufficient. Analysis so far suggests that a classification that results in 5–10 land cover classes may lead to the lowest overall uncertainty. Further data compilation and analysis is needed and possible. This has already started. The IPCC support office is providing support to full system carbon accounting.

An effective mechanism for reducing carbon emissions through avoided deforestation would have related, but separate, mechanisms at the international and national levels. Between countries, political negotiations should be convened to establish commitments to baseline and target emission levels. Countries that attain superior performance in avoided carbon emissions through avoided emissions should be eligible for carbon offset payments or credits through multi-lateral or bilateral arrangements.

Within each non-Annex I country that voluntarily participates in the new REDD rules, there should be scope for flexible rules to create positive incentives for rural and forest-dependent people to benefit from more sustainable and clean development pathways. Such incentives would ensure the sustainability of the carbon stocks and reserve more of the country's national natural capital for the future. A number of countries have gained experience with such mechanisms already, and pilots exist elsewhere. Here we recommend that individual countries involved in the international mechanism should have the flexibility to meet avoided carbon emission targets through national mechanisms appropriate to their individual country conditions, following principles already established among Annex 1 countries.

### *Benefits and Impact of Activity*

The current ‘avoided deforestation’ debate offers a chance to correct some of the major inconsistencies in the current system of carbon trading. Some of the key constraints that need to be overcome relate to scale, scope, political commitment, technical procedures and data quality. Best practice is emerging on the types of national and local mechanisms that countries can apply with much lower transaction costs than current CDM projects. Avoided deforestation with sustainable benefits can generate both local and global benefits. Research by the ASB partnership and others shows that intermediate land uses can store significant quantities of carbon, maintain flows of ecosystem services, generate good economic returns and reduce pressure on remaining.

### *Lessons Learned and Issues for Wider Application*

We can learn from the rules of the Kyoto Protocol that already apply between Annex-I countries, where all land use and land cover changes is accounted for, without restriction to any specific concept of ‘forest’, and without loss of national sovereignty over mechanisms. That accounting framework includes all changes in carbon stock which includes peat lands, trees outside forests, agroforestry lands plus flows of other greenhouse gasses.

A simple solution to the issue of “avoided deforestation” at the international level would be to allow developing countries to be voluntarily listed in a new Annex X. These countries would follow current rules for land use and land cover related emissions that exist between Annex-I countries, while leaving the energy related emissions for future consideration. The Clean Development Mechanism would still apply in the energy sector, but the issuance of “carbon credits” and associated markets would follow established procedures for Annex-I countries. No new procedures will be needed and transaction costs can be much reduced.

Once the playing field is selected and the rules of the game are set (e.g., AFOLU accounting at the national level), the real “game” can begin: determining the baseline of expected emissions that will be the basis for deciding what would constitute “reduction.” In some ways this is akin to a market where national self-interests need to balance out across a range of current issues, including world trade in agricultural and forest-derived commodities.

National and sub-national governments would need to know how much “avoided emissions” they could provide, and at what cost. Summary data of this type would require appraisal of scenarios for integrating economic development and land cover change. Currently, such estimates are not available, although there have been some promising advances in the countries of Meso-America.

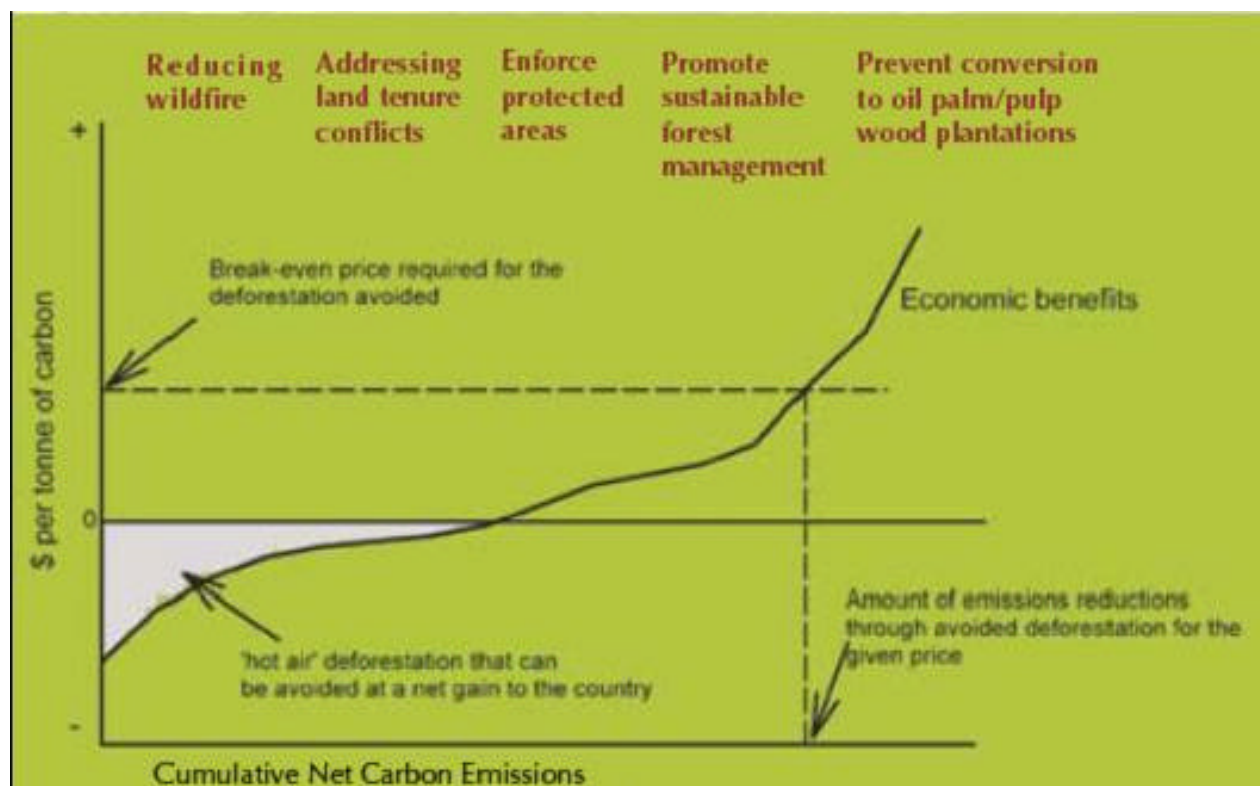
In an earlier phase of the discussions on clean development mechanisms, an inventory was made of “abatement costs,” largely in the energy sector. These results indicated that there was a fraction of “hot air” emissions that could be avoided at negative total economic costs, as they generate net economic costs at the societal level. There is also a range of emissions associated with moderate economic gain that could be offset at feasible levels of financial transfer. There is also likely to be a range of emissions associated with substantial economic gains that could not be offset under current carbon prices. Figure 3.8 presents a schematic view of these different types of avoided emissions, plotted in terms of economic benefits from carbon emission against the value of carbon. In addition, displayed across the top of figure 3.8 are some of the policy options that countries might promote in order to achieve different levels and types of emissions.

For the avoided deforestation debate in tropical countries, there are not, to our knowledge, any estimates available for the cumulative abatement costs (see figure 3.8). As an extension of the ideas

presented in this brochure, the ASB consortium for Indonesia is currently undertaking such an analysis for representative areas of Indonesia for the period since 1990.

Best practice is emerging on the types of national and local mechanisms that countries can apply to reduce carbon emissions from avoided deforestation, potentially with much lower transaction costs than current CDM projects. Incentive-and rights-based mechanisms can be put in place to reduce carbon emissions from avoided deforestation, while sustaining the asset base, rights, and well-being of people dependent on those resources. Countries such as Costa Rica and Mexico already have substantial experience in implementing such mechanisms at the national and sub-national scale. Large-scale afforestation programs, such as currently implemented in Indonesia, China, and India, could be revised to better address avoided carbon emissions. Forest, landscape, and watershed management projects can be revised to provide greater incentives to avoid carbon emissions through avoided deforestation. Case study evidence from across Asia and a pan-tropical synthesis show that realism, conditionality, voluntarism, and pro-poor are important criteria for evaluating the performance of incentive and rights-based mechanisms

**Figure 3.8. Schematic tradeoff between reduced greenhouse gas emissions through avoided deforestation and national economic development opportunities.**



Source: ICRAF

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Murdiyarsa, D., and H. Herawati. eds. 2005. "Carbon Forestry: Who Will Benefit?" Proceedings of a Workshop on Carbon Sequestration and Sustainable Livelihoods, 215pp. held in Bogor February 16-17, 2005. CIFOR, Bogor, Indonesia. VIII, ISBN: 979-3361-73-5.

Murdiyarsa, D., and M. Skutsch. eds. 2006. *Community Forest Management as a Carbon Mitigation Option: Case Studies*, 125p. Center for International Forestry Research (CIFOR), Bogor, Indonesia. ISBN: 979-24-4660-5.

Murdiyarsa, D., A. Puntodewo, A. Widayati, and M. van Noordwijk. 2006. *Determination of Eligible Lands for A/R CDM Project Activities and of Priority Districts for Project Development Support in Indonesia*, 39p. Center for International Forestry Research (CIFOR). Bogor, Indonesia. ISBN: 979-24-4622-2.

## **Web Resources**

[www.worldagroforestrycentre.org/sea/networks/rupes](http://www.worldagroforestrycentre.org/sea/networks/rupes)  
<http://www.cifor.cgiar.org/carbofor/ref/home/index.htm>  
<http://www.worldagroforestry.org/es/default.asp>

<http://www.worldagroforestry.org/sea/Networks/RUPES/index.asp>; <http://www.asb.cgiar.org/>  
<http://www.ipcc-nggip.iges.or.jp/tsu/tsustaff.htm>  
<http://www.adb.org/Documents/Reports/ALGAS/Summary/default.asp>

This Profile was prepared by Meine van Noordwijk, Brent Swallow, Lou Verchot, and Joyce Kasyoki; World Agroforestry Centre (ICRAF).

## **Innovative Activity Profile: On-farm Integration of Freshwater Agriculture and Aquaculture in the Mekong Delta of Vietnam – The Role of the Pond and Its Effect on Livelihoods of Resource-poor Farmers**

### *Summary*

Where there are abundant freshwater resources, there are valuable opportunities to integrate terrestrial and aquatic crops exist. This is illustrated by examples from the Mekong delta, where high-yielding rice was the priority crop but large areas of rice fields and fruit orchard ponds were underused. The development of integrated agriculture-aquaculture (IAA) systems enhances on-farm nutrient recycling and increases the total farm output. It is much less capital intensive and risky than conventional aquaculture methods and thus is attractive to both rich and poor farmers.

The adoption of IAA-farming was influenced by a combination of bio-physical, socio-economic and technological settings at community, household and farm level. First at community level, agro-ecology and market accessibility are major driving factors. Better off farmers, with good access to markets, still tend to favour higher profitability, high input aquaculture systems. But IAA-farming formed an important innovation especially in those areas with poorer market access or where farmers faced significant land, capital, or labour constraints.

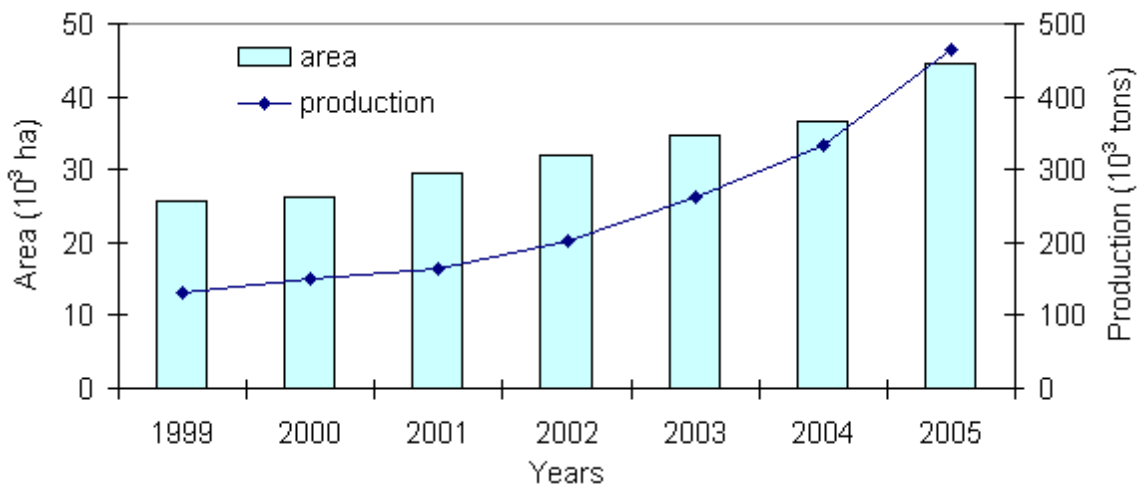
The main use of the pond is to recycle on-farm nutrients while growing fish for home consumption or income generation. The results from testing the system with a range of farmers in the Mekong Delta show clearly that the "conventional, linear" approach of technology transfer, needs to be replaced by the Participatory Learning in Action approach. This enables the concept to be tailored to the different needs and circumstances of various producers. In addition, systems of IAA-farming need to take into account integration with external inputs and diversification towards more commercially valuable crops. This creates new off-farm jobs and will particularly benefit poor households.

### *Introduction*

In areas with abundant freshwater resources, numerous options to integrate terrestrial and aquatic crops exist. Agricultural restructuring and diversification have been considered important for rural economic development and poverty reduction. Before 1999, high-yielding rice culture was the first priority for food security and export. Thus, a vast area of rice fields and fruit orchard ponds remained under-used from an aquaculture point of view. In 1999, a Sustainable Aquaculture for Poverty Alleviation (SAPA) Strategy and Implementation Program was launched by the Vietnamese government as a part of a wider Poverty Reduction Program (Luu 2002). The goal was to culture fish, prawn or shrimp together with land-based crops and livestock on the same farm, further referred to as integrated agriculture-aquaculture (IAA) systems (Nhan et al. 2007). In areas with abundant freshwater resources, numerous options to integrate terrestrial and aquatic crops exist.

In the period 1999-2005, the freshwater aquaculture farming area increased steadily, on average 12 percent per year, while the aquaculture production grew even faster with 42 percent per year, especially between 2002 and 2005 (figure 3.9). This expansion was in part the results of the development of intensive *Pangasius* culture, characterized by the use of manufactured feeds, by high investments and by economic risks, making it the domain of rich farmers (Hao 2006; Nhan et al. 2007). IAA-farming, in contrast, enhances or facilitates on-farm nutrient recycling and increases the total farm output, for rich and poor farmers (Edwards 1998; Prein 2002).

**Figure 3.9 Area and production increases in freshwater aquaculture in Vietnam during the period 1999-2005.**



Source: Authors elaboration

To stimulate the development of sustainable agriculture and to improve small-scale farmer's livelihoods in the Mekong delta, two projects were carried out between 2002 and 2006: (1) Improved resource use efficiency in Asian integrated pond-dike systems (Pond-Live) funded by the European Commission, and (2) Impact assessment of policy reforms to agricultural development (IPAD) funded by the Vietnamese Ministry of Agriculture and Rural Development. Based on experiences from these two projects, this paper explores the major factors influencing the adoption of various types of aquaculture, and describes the resource flows and reviews roles of ponds in farming system in the Mekong delta. Subsequently, implications for sustainable land management, lessons learned for practical application and policy recommendations are given.

#### *Project Description*

The Pond-Live project was implemented at three different sites in the Mekong delta, with the goal to improve resource use efficiency of freshwater IAA-systems (Nhan et al. 2007). A Participatory Learning in Action approach was applied, passing through six phases: (1) expert consultation and literature reviews, (2) formulation of problems and identification of key research and development issues, (3) analysis of interactions among household's conditions and IAA-farming performance, (4) on-farm monitoring of pond nutrient flows, (5) on-farm technology interventions, and (6) evaluating, sharing, and dissemination of research results, and proposing further improvements (Little et al. 2007a). Phase 1, 2, and 3 were carried out in the first year of the project. From the second year onward, phases 4, 5, and 6 were implemented and the process was repeated to create a cycle of continuous development of adaptive technologies of higher productivity and better nutrient use.

The IPAD project, carried out at eight different sites, aimed to identify impacts of policy reforms on changes in agricultural production and household's livelihoods. The study sites were located in four districts: Cao Lanh and Lai Vung (Dong Thap province), and Chau Thanh and Cho Gao (Tien Giang province), with two sites per district. The project was implemented following phases 1, 2, 3, and 6.



### *Presentation of Innovation: Adoption of Aquaculture Practices*

In the Mekong delta, very few poor farmers adopt aquaculture. Results from the Pond-Live project showed that only 6 percent of poor farmers practiced aquaculture compared to 42 percent and 60 percent for intermediate and rich farmers, respectively (Nhan et al. 2007). Richer farmers tended to intensify the fish production stocking high-value species like catfish (*Pangasianodon hypophthalmus*) or climbing perch (*Anabas testudineus*) and using commercial feed. The IPAD project confirmed these findings. Between 2000 and 2004, the percentage of poor households practicing aquaculture increased only 2 percent, while 12 percent and 15 percent, more households of intermediate and rich farmers, respectively, took up aquaculture (table 3.5).

**Table 3.5 Percentage of Farm Households Practicing Freshwater Aquaculture in 2000 and 2004 by Wealth Groups—Poor, Intermediate, and Rich**

<b>Wealth groups</b>	<b>N</b>	<b>2000</b>	<b>2004</b>	<b>Difference</b>
Poor	276	4.3	6.2	1.8
Intermediate	303	44.6	56.1	11.6
Rich	292	48.3	63.4	15.1

N= the number of households in each group; Percentages are always given as a fraction of n.

Source: From IPAD project (unpublished data).

The contribution of farming activities to household income was lower for the poor than for the intermediate and the rich. Off-farming or non-farming jobs are relatively more important for poor people, who mostly considered crop production as their most important economic activity and aquaculture as least important. From 2000 to 2004, the contribution of aquaculture to household income increased, but this effect only occurred among the intermediate and the rich groups.

In the Mekong delta, the adoption of IAA-farming was influenced by a combination of bio-physical, socioeconomic, and technological settings at community, household, and farm level. First at community level, agro-ecology and market accessibility are major driving factors. In rice-dominated areas, more farmers practiced IAA-farming than in fruit-dominated areas. Rich farmers with good market accessibility tend to practice commercially-oriented aquaculture systems relying heavily on external inputs. Second, the household's wealth status and resource base determine whether the pond culture is adopted or rejected. Nhan et al. (2007) identified the major reasons why farmers adopt aquaculture: (a) increased use of on-farm resources, given positive contributions of government advocacy, suitability of soil and water, recycling of nutrients, pest control in rice fields, and creation of jobs for family members; (b) income generation through aquaculture, (c) environmental improvements, and (d) improved nutrition of household.

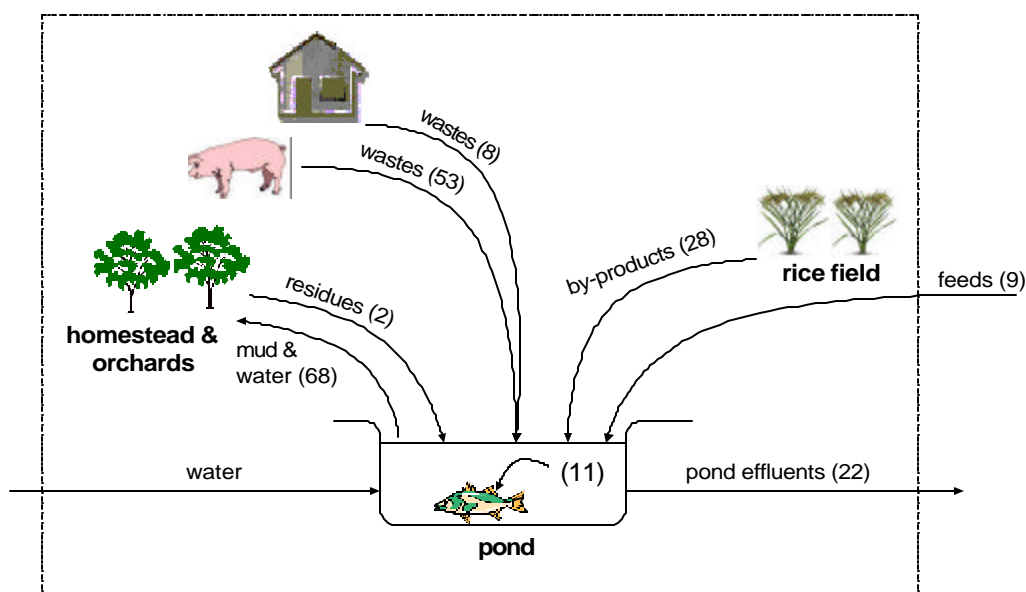
Major factors why farmers did not take up pond farming include: (a) insufficient capital to introduce technologies; (b) insufficient land holding; (c) difficult farm management (e.g., family labor, distance between homestead and farm land, and poor access to extension service); (d) pesticide use for crop production conflicting with aquaculture activities; and (e) poor soil and water quality. Finally, factors at community and household level, pond physical properties (i.e., pond width and depth) and the availability of nutrient sources (on-farm or off-farm) as pond inputs together largely determine the type of farming systems adopted. Three major types of IAA-systems could be distinguished: (a) low-input fish farming, (b) medium-input fish farming, and (c) high-input fish farming (Nhan et al. 2006; Nhan et al. 2007). The low-input farming system is commonly practiced in the fruit-dominated area, the medium-input system in the rice-dominated area, and the high-input system in the rice dominated area with good market accessibility.

### On-farm Resource Flows and the Role of the Pond

In the Mekong delta rural areas, most of households have a pond nearby the homestead. In the past, the main purpose of digging ponds was to raise the level of low-lying grounds for house construction or for orchards. Fish farming was not considered a high priority as wild fish was abundant in rice fields, flood plains, canals, and rivers. Currently, farm households not practicing IAA-farming do not stock hatchery juveniles in their pond, which is used for wild fish capture instead.

The pond within IAA-systems plays multiple roles, which differ from one system to another. Currently, the main use of the pond is to recycle on-farm nutrients while growing fish for home consumption or income generation (Nhan et al. 2007). In low- and medium-input fish farming systems, on-farm nutrients are the main input source of the pond (figure 3.10). Livestock and rice field components that receive nutrients or energy mostly from off-farm sources provide important amounts of nutrient-rich wastes and by-products (Nhan et al. 2006). By-products collected from rice fields include not only rice residues but also crabs and golden snails. About 11 percent of N in these wastes or by-products are thrown in ponds and are harvested as fish, while 67 percent accumulate in the sediments and 22 percent are lost through water exchange. Annually, farmers typically extract water from the pond to irrigate fruit crops cultivated on dikes during the dry season, and annually remove pond sediments to fill up orchard dikes adjacent to the pond. By doing so, the nutrient-rich mud and water can be considered as fertilizers for terrestrial crops within the system. Integrating aquaculture into existing land-based farming systems yields various benefits to farmers: (a) a higher fish production, (b) low external nutrient inputs, (c) treatment of wastes/by-products from terrestrial crops, and (d) storage of nutrients in pond sediments for later (re)-use as fertilizer. In contrast to intensive fish farming, these benefits are within reach of poor farmers.

**Figure 3.10. Bio-resource Flows of an IAA-pond with Medium-input Fish Farming in the Mekong Delta**



Note. The number in the parenthesis of each arrow is average percentage of total food N inputs of the pond. Dotted lines refer to farm boundary.

Source: Adapted from Nhan et al., 2007

### *Benefits of IAA and Its Implications for Sustainable Land Use Management*

IAA-farming can have a positive impact sustainable land management. These impacts include:

- Integrating aquaculture into existing land-based farming systems enhance farm resource use through creating new nutrient cycles between farming components, and improving the overall food productivity and farming profitability.
- A diversified IAA-farming system with more synergisms between farm components means a more economically stable farming system. For example, recently in the Mekong delta livestock production is usually not stable because of disease outbreaks and fluctuations of input and output market prices. Thus, fish produced within IAA-system can compensate possible losses of livestock production.
- IAA-farming rehabilitates farm soil. Intensive fruit and rice production highly depends on heavy use of inorganic fertilizers. Introducing fish into orchard ponds or rice fields enhances farm organic matter recycling and maintains the high fertility of orchard dikes and rice field soil.
- Improved nutrient recycling between farming components in IAA-systems results in a higher fraction of nutrient inputs ending up in farming products while smaller amounts of nutrients accumulate within the system or flow into the environment.
- IAA-farming systems produce low-cost fish not only for IAA-household but also for poor consumers. In the Mekong delta, fish contributes to about 76 percent of the average supply of animal protein (Haylor and Halwart 2001; van Anrooy 2003) while wild fish resources have declined because of rice intensification and over-fishing.

### *Lessons Learned and Issues for Wider Applicability*

Lessons learned from applying a “Participatory Learning in Action” approach to develop IAA-farming are:

- IAA-systems are very diverse. Identification of biophysical, socioeconomic, and technical factors interacting at different levels (e.g., community, household, and pond; phase 1-3) is of great importance in order to identify meaningful interventions at site or household level.
- Farm bio-resource flow diagram is an important tool. At phases 2 and 3, farmers usually have a wide range of options, paying much attention to a particular component rather than the whole system. The diagram helps farmers fully identify their resources and recognize various options to improve their farming system.
- A key factor to success of the Participatory Learning in Action approach is the participation of all stakeholders, most importantly local farmers and extension workers. Having said this, the stakeholders need to understand the whole process of a project and goals and outcomes of each phase within the process. During field visits, researchers and extension workers need to help cooperating farmers to gradually upgrade their capacity in technology development through phenomenon observation and explanation, collecting simple data, explaining on-farm trial results, identifying problems and suggesting possible solutions.
- Improved technologies are context-specific. Field visits and discussions among cooperating farmer, local farmers, extension workers, and researchers are necessary so that improved technologies in one place can be taken up adaptively in another.

- Unlike on-station experiments, on-farm trials lack real replications and data variations between farms are large. Reducing the number of parameters sampled and increasing the number of farms would be advisable. Multivariate data analysis is an important tool in analyzing data and interpreting results (Nhan et al. 2006).

*Investment Needs and Priorities*

- The government advocated developing IAA-farming as a way of poverty reduction. Unfortunately most poor farmers did and could not respond. The government and extension agencies need to define and implement appropriate solutions. Some of these may include:
- The “conventional, linear” approach, that focuses mainly on technology transfer, needs to be replaced by the Participatory Learning in Action approach, giving attention to integrated resources management rather than a single component.
- A package of immediate and long-term support actions with different choices of appropriate technologies should be provided to pull poor farmers into IAA-farming. Time must be taken to categorize local biophysical and socioeconomic contexts, in order to provide tailor-made support actions. Farmers often take up new or improved technologies when these constitute slight improvements to traditional farming practices. Once a small improvement has been proven, other will follow more easily.
- Farm management skills need to be improved considering the complexity of integrated farming.
- Finally, extension of IAA-farming in the Mekong delta originally focused on on-farm integration only. Such an approach will hardly produce the optimal fish yield considering the large variation in the types, quantity, and quality of on-farm wastes or by-products available. A “one solution fits all” is not feasible.
- Integration requires that external contexts are taken into account. Therefore, propagating IAA-farming, should take into account integration with external inputs and diversification toward more commercially valuable crops. It should be noted that such an approach would create new off-farm jobs and raise the demand for expert advice. The latter concurs with the creation of new jobs directly, and will in the long run benefit more poor households than immediate or well-off households (Edwards 1998; Little et al. 2007b).

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## **Section III-B. Rain-fed Farming Systems in Highlands and Sloping Areas**

### *Overview*

Farming systems in highland and sloping areas are estimated to provide for an agricultural population of 520 million people, who cultivate 150 million ha, of which 20 percent is irrigated. There is intense population pressure on the resource base which averages 3.5 persons per cultivated ha.

In most cases these are diversified mixed crop-livestock systems, producing food crops such as cassava, sweet potato, beans, cereals, and perennial crops such as banana, coffee, and fruit trees, among others. Crop productivity is reduced through the high altitudes, lower temperatures, and shorter cropping seasons compared to the lowlands. Steep slopes, and thin soil horizons that are prone to erosion characterize these systems. Livestock can be an important system component that is dependent on the extensive upland grazing areas. The sale of cattle or small ruminants is often the main source of cash income. The highland areas are in many locations home to last remaining primary forests. Extensive forested areas are sometimes used as grazing areas, and constitute agricultural land reserves that can be put into production through slash-and-burn techniques. In the Andes, Southeast Asia, and South Asia, uplands are home to large groups of indigenous population. Poverty is usually high.

With intense population pressure on the resource base, farm sizes are usually small. Declining soil fertility is a big problem because of erosion, biomass shortage, and shortage of inputs. Given the lack of road access and other infrastructure, the level of integration with the market is often low. There are few off-farm opportunities in the highlands, and seasonal migration is often necessary to find additional income.

### *Potentials for Poverty Reduction and Agricultural Growth*

The driving forces for poverty reduction will be emigration (exit from agriculture) and increases in off-farm income. Diversification, especially to high value products with relatively low transport and marketing costs, will also contribute significantly to poverty reduction. This can include tree crops such as fruit trees, coffee, tea or in more temperate areas olives, or grape vine, among others. Livestock production has also a potential to be further developed.

## **Investment Note: No-Burn Agricultural Zones in Honduran Hillsides – Better Harvests, Air Quality, and Water Availability by Way of Improved Land Management**

### *Summary*

Hillsides are an important agroecosystem in the tropics and sub-tropics. Traditional slash-and-burn practices, widely used in the hillside areas of Central America, have been a driving force in agricultural expansion and landscape degradation. Farmers in a village called Quesungual developed a slash and mulch system and eliminated the burning. This was the origin of QSMAS. With Honduran government and FAO support, a process of validation of the system, with the active participation of farmers, was initiated. Farmers practicing QSMAS are able to produce sufficient maize and beans to meet their household needs and sell excess in local markets. In addition, innovative farmers are intensifying and diversifying this system using vegetables and market-oriented cash crops as well as raising livestock. QSMAS demonstrated a high degree of resilience to extreme weather events such as the El Niño drought of 1997 and Hurricane Mitch in 1998. Permanent cover protects the soil from raindrop impact and crust formation, while minimizing surface evaporation. In addition, surface residues favor nutrient recycling, improve soil fertility and could result in higher carbon storage in soils.

The success of QSMAS is a reflection of a community-based learning process in which local people and extension service providers share ideas and learn together. At the landscape level, QSMAS has contributed to the conservation of more than 40 native species of trees and shrubs. Newer QSMAS farms (2 to 5 years) serve as sinks for methane (CH<sub>4</sub>) with low emission levels of nitrous oxide (N<sub>2</sub>O). These results help mitigate climate change.

### *Key Sustainable Land Management Issues*

Hillsides are an important agroecosystem in the tropics and subtropics. More than 11 percent of the agricultural lands in these areas are classified as hillsides (4.1 million km<sup>2</sup>). Tropical hillsides in Latin America, Africa, and Asia are home to about 500 million people, 40 percent of them living below the poverty line.

In southwest Honduras, most farms are small-scale (80 percent are less than 5 ha) and located on steep hillsides (5 to 50 percent slope). The Quesungual Slash-and-Mulch Agroforestry System (QSMAS) is an indigenous land management practice based on planting annual crops with naturally-regenerated trees and shrubs. QSMAS enables farmers to achieve food security by simultaneous improving harvests and soil fertility.<sup>1</sup> The investment note explains how CIAT and partners combine scientific and local knowledge to further improve the land management practice and foster its use.

Stagnated agricultural productivity coupled with rapid population growth, are causes of uncontrolled expansion of agriculture and ranching into hillside forests. Resulting environmental damage includes not only the loss of trees but also water and soil losses from runoff and erosion. Reversing land degradation while increasing food production is an essential strategy to improve both rural livelihoods and natural resource management in hillsides regions (Ayarza and Welches 2004).

Traditional slash-and-burn practices have been a driving force in agricultural expansion and landscape degradation. Such systems are widely used in the hillside areas of Central America. A number of factors have led to this form of land use, and include:

- Lack of opportunities for off-farm employment.
- Scarce resources to invest in intensifying production.

- The relative ease of slash-and-burn system also produces quick economic benefits to farmers.
- A scarcity of technical assistance and little adaptation of appropriate technologies that promote soil cover and eliminate the need for burning.
- Increased urbanization, therefore rural areas are rarely a priority for central governments.
- Few national or local policies implemented to encourage the use of environmentally-friendly production practices.

#### *Building on Lessons Learned from Past Experiences*

Although small farmers extensively practice slash and burn, a small group of farmers in a village called Quesungual came up with an important change; they planted crops under a slash and mulch system and eliminated the burning – this was the origin of QSMAS. In the early 90s, a development project of the Honduran government with the support of FAO noted this anomaly and concentrated efforts to improve and generalize this practice in the region. The project initiated a process of validation with the active participation of farmers. Local organizations, farmer communities, and small enterprises grew along with the process of supporting the adoption of improved QSMAS practices. Widespread adoption of QSMAS was supported with a local government ban on burning. Before long, several villages of the region achieved a status almost completely foregoing the use of fire.

Farmers practicing QSMAS were soon able to produce sufficient maize and beans to meet their household needs and sell excess in local markets. In addition, innovative farmers are intensifying and diversifying this system using vegetables and market-oriented cash crops as well as raising livestock. QSMAS demonstrated a high degree of resilience to extreme weather events such as the El Niño drought of 1997 and Hurricane Mitch in 1998. Permanent cover protects the soil from raindrop impact and crust formation, while minimizing surface evaporation. In addition, surface residues favor nutrient recycling, improve soil fertility, and could result in higher carbon storage in soils.

QSMAS plots have three layers of vegetation: (a) mulch, (b) crops, and (c) dispersed shrubs and trees. It starts with the selection of a well-developed fallow (with numerous and diverse trees and shrubs). Farmers selectively slash and prune the fallows, remove firewood and trunks, and uniformly distribute the biomass (leaves and fine shoots) as mulch. Then, “pioneer” crops such as sorghum (*Sorghum vulgare*) or common beans (*Phaseolus vulgaris*), whose seedlings are capable of emerging through the mulch, are sown by broadcast. Maize (*Zea mays*) is not sown as a pioneer crop because: (a) the abundant mulch restricts the emergence of seedlings, and (b) late season planting (August) does not provide adequate soil moisture for grain filling.

For about 10 years after the pioneer crop, the system maintains agricultural production based on the regrowth potential of trees in the system. QSMAS annually produces maize intercropped with beans or sorghum. Management is zero-tillage, with continuous slashing and pruning of trees and shrubs for firewood to avoid excessive shading of the crops. Continuous mulching from leaf litter, slashing of trees and application of crop residues is supplemented with spot fertilization technologies, and occasional use of pre-emergence herbicides (figure 3.11).

A major obstacle to larger-scale implementation of QSMAS was not the small farmer. Extensionists and their organizations often maintained a monocrop production bias and opposed the comprehensive approach of QSMAS. A lack of training in demand-driven participatory extension dominated rural development projects, which focused efforts on physical, supply-driven indicators.



Although much was said about collaboration between local and professional knowledge systems, the approach was rarely implemented (Welches and Cherrett 2002).

The success of QSMAS is a reflection of a community-based learning process in which local people and extension service providers share ideas and learn together. The strategy to promote adoption and integration consists of three main components: (a) collective action, (b) technological innovations, and (c) policies and negotiations.

**Figure 3.11 Quesungual Slash-and-Mulch System in Honduras.**



Source: CIAT

The project promoted collective action by strengthening the capacity of households (both men and women), local groups, educational institutions, and development organizations to organize and identify leaders and negotiate their interests with government representatives, service providers, and policy makers. Several local development organizations learned to devise action plans to improve agricultural practices using QSMAS.

Training services strengthened entrepreneurial capacity of men and women to transform and add value to agricultural products and sell them in the market. Technological innovation enhanced the capacity of farmers and household heads to adapt the components of the QSMAS to their production systems and to develop new and appropriate innovations according to their own land and labor constraints.

The bargaining capacity of local communities to negotiate incentives and regulations supporting the adoption of the QSMAS was strengthened. Local government officials were informed of the negative effects of burning on crop production and water availability. This resulted in laws with severe penalties for those using fire as part of agricultural practices. Other laws were advanced with respect to common forest lands and water reservoirs. Significant improvements in financial services and infrastructure were negotiated with the Honduran government.

*Opportunities for Sustainable Land Management*

Letting soils “rest” as fallow after a cropping cycle has been a traditional management practice throughout the tropics to restore soil fertility. In southwest Honduras, successful restoration of soil fertility after cropping for 2 to 3 years usually requires 14 to 20 years of fallow period. Use of QSMAS can produce 10 years of crops with fallow period of 5 to 7 years. In the QSMAS plots, a key

factor that contributes toward the restoration of soil fertility is the coexistence of deciduous trees and shrubs. These serve as sources of mulch that protect soil, retain water, and cycle nutrients during both production and fallow periods. An improved agricultural productive capacity together with provision of a number of environmental services (includes reduced soil losses and improved water quality) can help convince farmers to move away from the traditional slash-and-burn system and toward QSMAS.

Recent research results have shown that the use of QSMAS generates both economic and environmental benefits. This should be an incentive to national and local authorities to encourage QSMAS. Socioeconomic and biophysical benefits QSMAS are many:

*Food security.* Farmers achieve productivity increases of traditional staple crops (i.e., maize, beans, and sorghum), and can diversify with other food crop options. Other benefits reported by QSMAS farmers are: improved incomes, less labor invested in land preparation and weed control, reduced costs of production, and higher net profits.

*Increased market involvement.* Surpluses from improved yields and crop diversification provided householders the production capacity to link with local markets.

*Other products.* The QSMAS had contributed to improved availability and quality of water not only to local communities but also to the users downstream. QSMAS farms are also good sources of firewood for domestic consumption.

QSMAS generated benefits at farm and landscape levels:

*Farm level.* The QSMAS has proved to be productive and sustainable while providing an improved physical, chemical and biological resilience to agricultural plots. According to farmers, the following are among the main biophysical benefits of the system: (a) reduced soil erosion, (b) improved soil water holding capacity when rainfall is erratic (irregular or insufficient), (c) improved soil fertility due to efficient recycling of nutrients through mulch, and (d) improved resilience of the system from natural disasters.

*Landscape level.* The adoption of QSMAS by farmers has contributed to improvements in environmental quality. The widespread use of the QSMAS has decreased soil losses, and it has reduced the sediments in watercourses. The QSMAS has contributed to the conservation of more than 40 native species of trees and shrubs. Newer QSMAS farms (2 to 5 years) serve as sinks for methane (CH<sub>4</sub>) with low emission levels of nitrous oxide (N<sub>2</sub>O). These results help mitigate climate change.

#### *Rationale for Investment*

QSMAS is a resource-efficient production system that improves livelihoods while conserving the natural resource base. The main reasons behind its successful adoption by farmers include:

1. Reduced soil losses due to erosion. A combined effect of permanent soil cover and presence of stones improves crop water productivity and water quality.
2. Increased availability of soil nutrients. Trees and organic resources maintain or even increase nitrogen and phosphorus, while enhancing soil biodiversity and biological activity.
3. The no-burn practices reduce negative effects on greenhouse gas emissions.
4. Conservation of trees and shrubs favors local biodiversity. Cumulative benefits of widespread QSMAS practices improve biodiversity of the landscape.

In the last decade, more than 6,000 resource-poor farmers have adopted QSMAS on 7,000 ha in the Lempira department, formerly the poorest region in Honduras. This response has generated a two-fold increase in crop yields (e.g., maize from 1200 to 2500 kg ha<sup>-1</sup>, beans from 325 to 800 kg ha<sup>-1</sup>) and cattle stocking rates, along with significant reductions in labor and agrochemical costs (Ayarza and Welches 2004; Clerck and Deugd 2002). By way of non-formal diffusion processes, the system has also been accepted among farmers of northwest Nicaragua.

Scientists from CIAT, FAO, and MIS (Integrated Soil Management) consortium conclude that the Quesungual system, or elements of it, could be adapted for use in hillside areas of Africa, Asia, and South America. The project supported by the Challenge Program for Water and Food (CPWF) expects to identify new areas that could be suitable for QSMAS and provide the tools for adapting and promoting the entire system or its components in these areas.

#### *Recommendations for Practitioners*

*Reach consensus:* The principle of QSMAS is SLM through the protection of the natural resources that are essential for agricultural productivity. The practices include (a) the use of local natural resources (i.e., vegetation, soil, microorganisms) with introduced crops, (b) field preparation without the use of burning or tillage, (c) the continuous slash and mulch of naturally-regenerated vegetation, and (d) spot application of fertilizers and occasional herbicide use. Successful implementation requires detailed discussion with farmers on all four components.

*Local knowledge:* The success of QSMAS depends on local perspectives and knowledge. Close collaboration with local farmers is essential in order to understand how to manage system components, particularly the native tree and shrub vegetation.

*Use local support:* A key factor for the widespread adoption of QSMAS was a decision taken in a local referendum to forbid the use of burning to prepare fields for planting. This couldn't have been possible without the support of local authorities, and a clear understanding of farmers of the negative effects of burning and the multiple biophysical and socioeconomic benefits from the restoration of soil organic matter.

*Train farmers:* Even though maintaining the QSMAS plots are not expensive, the initial establishment investment, especially labor, is higher than the traditional slash-and-burn system. Extensionists need to explain the potential benefits in return of their labor and costs. The use of QSMAS has some limitations: (a) lower rates of seed germination when mulch layer is too thick, (b) higher incidence of pests and diseases during the initial years due to the mulch and the increased humidity due to shade, and (c) a similar or even reduced productivity during the first year (FAO 2001).

Although great potential exists for the QSMAS to be adopted in other regions of the world, it is important to realize that any project supporting its validation requires substantial time and resources commitments within the context of a long-term framework. Additional to research for development investments would enable more farmers to adapt QSMAS to their local biophysical and socioeconomic conditions. Investments would also permit researchers and development practitioners to analyze the feasibility of establishing payments for environmental services from smallholder QSMAS. Fostering positive incentives for sustainable land management on and off farms can improve the productivity and resilience of tropical hillside agroecosystems.

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## Web Resources

- <http://www.ciat.cgiar.org/>  
[www.waterandfood.org/](http://www.waterandfood.org/)  
<http://www.fao.org/FOCUS/E/honduras/agro-e.htm>

[http://www.handsontv.info/series2/foodworks\\_reports/shortagetosurplus\\_honduras.html](http://www.handsontv.info/series2/foodworks_reports/shortagetosurplus_honduras.html)  
<http://www.worldagroforestrycentre.org>  
[http://siteresources.worldbank.org/EXTAGISOU/Resources/Module5\\_Web.pdf](http://siteresources.worldbank.org/EXTAGISOU/Resources/Module5_Web.pdf)

## **ENDNOTES**

1. The system is being used within the Lempa river upper watersheds in the department of Lempira, Honduras (around 14° 4' 60" N, 88° 34' 0" W) at 200-900 masl. The regions' life zone (Holdridge) is a subhumid tropical semi-deciduous forest and pine trees, while its climatic classification (Köppen) is a Tropic Humid-Dry (Aw) region with a bimodal rainfall distribution during the year. Mean annual precipitation is about 1,400 mm falling mainly from early May to late October, with a distinct dry season of up to six months (November –April). During the dry season strong winds blow from the North and the enhanced evapotranspiration rates cause severe water deficits (over 200 mm) until the onset of rains. Temperature ranges between 17-25 °C. Soils are classified as stony Entisols (Lithic Ustorthents) influenced by volcanic ashes associated with igneous and intrusive rocks, usually with low labile P (i.e., <5 mg kg<sup>-1</sup>) and low soil organic matter content (2.8-3.9 percent) with pH values ranging from 4.1 to 6.2.

2. Adapted from Ayarza and Welchez, 2004.

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## **Investment Note: Beans: Good Nutrition, Money and Better Land Management - Scaling Up in Africa?**

### *Summary*

The common bean is a major staple food crop in Africa. PABRA (the Pan-African Bean Research Alliance) aims to enhance the food security, income and health of resource-poor farmers in Africa through research on beans. Partners operate in different agro-ecological and socio-economic environments through a series of collaborations with local agencies and directly with farmers in 'research groups'.

The improved bean varieties have environmental benefits beyond the farm. Because, for example, some require less cooking time than traditional varieties, fuelwood consumption (and the time spent collecting fuel) has fallen sharply, releasing women especially for other livelihood activities. Innovative bean farmers used improved technologies from service providers (such as pest tolerant high yielding varieties, fertilizers, commercial pesticides and improved cultural practices) to blend with local options (the use of wood ash, cow urine, cow shed slurry, and local plant extracts for pest control; animal and green manure for improving soil fertility; improved agronomy through cultural practices such as mixed cropping, staggered planting and use of local crop cultivars). While the immediate benefit was yield increases from improved bean management, the second, and broader and even more exciting achievement was the enhancement of farmer innovation and farmer to farmer communication.

PABRA researchers are striving to improve the nutritional content of beans and to improve market access. But the PABRA approach helps actively to explore other technologies and actively to seek improved services (such as quality seed, markets, credit, improved livestock, fertilisers, tree nurseries, irrigation facilities, soil and water conservation methods). District authorities in Malawi, Tanzania, Kenya and Uganda use the PABRA farmers groups to develop and implement community based project proposals.

### *Characteristics of Key Sustainable Land Management Issue*

Beans are popular in Africa, and for good reason. Beans are healthful, profitable, and with good management, contribute to farm diversification and productivity. Can more farmers benefit from cultivating these fast-growing legumes? Africans confront numerous agricultural, communication, and transportation challenges. This investment note explains how CIAT and partners combine their scientific, organizational, and marketing efforts to address these challenges and reach more farmers.

### *Key Sustainable Land Management Issues*

Natural resources are the key to rural development in Africa (Anderson 2003). Despite their importance, a majority of Africans still face both food shortages and degradation of their natural resources. Two-thirds of the population (405 million people) lives on small-scale farms (Conway and Toenniessen 2003) where declines in soil fertility severely reduce harvests.

Although overexploitation of natural resources comes in many forms, the results are the same: a loss of both productive capacity and resilience. Soil degradation threatens: (a) the sustainability of agricultural yields, and (b) the ability of agriculture to deliver crucial services, such as water availability, biodiversity, and carbon storage.

For many generations, traditional farm practices met household food needs. Population growth and accompanying pressure on land, however, have stressed this equilibrium. Farmers typically respond

by either intensifying agricultural production or expanding into marginal lands (Dixon et al. 2001). Nevertheless, harvests from these efforts are typically low because no or few investments in soil fertility maintenance are made. Although chemical fertilizers have produced impressive yield gains in much of the world, fertilizers are rarely available or too expensive in much of Africa (Crawford et al. 2003; Gregory and Bumb 2006). There are also serious misunderstandings regarding fertilizer. For example, some farmers believe that, to be effective, the fertilizer actually needs to touch the seed – which in fact hinders germination and damages both the crop and the farmers’ faith in the technology. Furthermore, the advice farmers are typically given in the use of fertilizer is poor – recommendations ignore crucial differences in soil type and, as importantly, the key economic factors of prices of both inputs and outputs (see Conroy et al, (2006). Local ways to enhance farm productivity are needed (Giller 2001).

#### *Lessons Learned from Past Experiences*

The common bean is a major staple food crop in Africa. Farmers plant approximately 4 million hectares, which represents 20 percent of the total crop area planted. In many parts of east, central, and southern Africa, beans are referred to as the “poor man’s meat.” Beans provide nearly 40 percent of dietary protein and are valued as one of the least expensive sources of protein. Many eat beans twice a day. During hard times in some areas, households survive on just one meal of beans.

A major lesson learned is the importance of having an active regional and local institutional partnership to facilitate the dissemination and scaling up of cropping and land management innovations. PABRA is the Pan-African Bean Research Alliance. PABRA’s goal is to enhance the food security, income, and health of resource-poor farmers in Africa through research on beans. PABRA works in partnership with farmers and rural communities, non-government organizations (NGOs), national agricultural research institutes (NARIs), traders and other private sector partners. Crucial roles and responsibilities of partners include improving bean varieties, producing and disseminating seed, sharing information, and training extensionists and researchers.

Collaborative PABRA efforts enhance farmer access to improved quality seeds that farmer prefer. This process involves:

- Understanding farm household needs and taste preferences, and their sources of bean seed;
- Supporting partners involved in decentralizing bean variety selection, seed production, and distribution;
- Strengthening and catalyzing partnerships with strategic actors;
- Facilitating access to information and preferred seed varieties by commercial seed producers;
- Providing key support services: technical inputs, outreach products, and co-learning;
- Sharing lessons learned, including successful cases of wider impact at local, national and regional level (e.g., Ethiopia, southern Tanzania) that demonstrate how change processes work with PABRA partners;
- Adapting lessons to new areas and crops (e.g., cassava, teff) with new partners.

The bean research network has worked together since the early 1980s, improving the productivity, resilience, and acceptability of bean varieties. NARS and extension partners released about 200 improved beans in 18 countries (figure 3.12). Partners operate in different agroecological and socioeconomic environments. PABRA partners have overcome production problems such as bean

pests and diseases and poor soil fertility; and have made new bean varieties available to more farmers.

**Figure 3.12 Eighteen member countries of the Pan-Africa Bean Research Alliance (PABRA).**



Source: CIAT

PABRA has fostered strategic partnerships that play complementary roles in reaching end-users. By late 2006, PABRA partner organizations had trained more than 300 associations with about 15,000 farmers. Topics included variety testing, seed production, and agronomic practices. Knowledge sharing among farmers has greatly accelerated technology dissemination and adoption. National programs have been encouraged to conduct participatory varietal selection or plant breeding with farmers. These approaches have ensured that new varieties are quickly made available to farmers before their formal release. To speed up dissemination, PABRA has supported the development of community-based seed production as an agro-enterprise strategy. Technical resource manuals in 11 local languages have been developed and supplied to farmers and extension organizations.

#### *Opportunities for Sustainable Land Management*

Beans generate environmental benefits on and off farm. Farmers often cultivate beans in rotation or association with other crops. This strategy diversifies farm production against risks and can enable farmers to improve soil fertility. Bean cultivation within a farm management strategy may enhance the yields of other crops such as maize.

Although PABRA has promoted the use of improved bean varieties that thrive in poor soils, such beans perform better when integrated with good farm management practices. PABRA researchers look for and examine a wide range of locally-generated solutions for improving soil fertility such as green manures and organic soil amendments. In many parts of Africa, bean crop residues are used as (a) a green manure to increase soil organic matter, or (b) a livestock feed with manure applied to



fields (in Ethiopia, Kenya, and Rwanda). PABRA also serves as a forum to share management practices.

Pests and diseases can destroy harvests and cause food shortages. The early 1990s were troubling times for both bean farmers and consumers in Eastern Africa. Bean root rot disease decimated harvests in intensely cultivated areas, causing severe food shortages and high prices. To help solve the problem, PABRA scientists from CIAT and the Institut des Sciences Agronomiques du Rwanda (ISAR) identified bush and climbing bean varieties with resistance to the disease. Partners introduced these varieties to Kenya and southwest Uganda.

Improved bean varieties are not the only way to achieve better harvests and possibly improve soil fertility. Climbing beans can generate higher yields than bush beans, enabling farmers to sustainably intensify production on tiny plots. Integrated pest and disease management (IPDM) can be effective in improving system outputs. Farmers typically combine local knowledge and researcher-generated innovations (e.g., timely planting, weeding, use of botanical pesticides, and sowing or use of Tephrosia to restore soil fertility while warding off pests).

Results show such practices are effective in countering bean root rot and other diseases and pests. According to PABRA, improved practices to counter pests, diseases and poor soils reached 400,000 farmers by 2005. Although this figure is well behind the numbers of those adopting improved varieties, it represents a very promising start.

Improved bean varieties have environmental benefits beyond the farm. Some of the improved beans require less cooking time than traditional varieties. Women report reduced fuelwood consumption of almost 50 percent. Women can also spend less time collecting firewood during the day, and can dedicate their effort to other livelihood activities.

#### *Rationale for Investment*

Beans can play a role in achieving SLM in Africa. The ability of beans to be profitable while contributing to overall farm production and resilience makes them an attractive crop for many African farmers. Evidence suggests that bean varieties generate substantial benefits for producers, consumers, and other bean supply chain actors. Significant impacts, however, tend to be found in areas of intense efforts to disseminate seed. As part of the revised PABRA strategy of 2003, the network aims to achieve greater use of improved bean varieties. The goal was to ensure the delivery and training in improved bean technologies to 2 million households (10 million end users) in 18 countries by 2008. Expectations have already been exceeded. As a result of the strategic partnerships, reach was about 6.5 million households (30 million end users) at the end of 2006. Critical to success was packaging of seed in small, affordable quantities. Fifty tons of seed can reach a million farmers with 50g of seed packets. More work is required in order to reach the hundreds of millions in need of improved bean technologies.

According to PABRA, farmers who planted improved varieties reported increased yields, had fewer losses to pests and diseases, enhanced family nutrition and health, and realized higher incomes. In some countries, bean research and development has brought substantial economic returns. For example, in Tanzania the internal rate of return to research investments was estimated at 60 percent over the 20-year period (1985 to 2005). Economic benefits can be seen from the farmer perspective. In eastern Democratic Republic of Congo, farmer incomes from beans increased nearly fivefold. Higher incomes were generated not only from increased bean sales for consumption, but also from the sale of seeds. In some countries, seed production and sale have become money-making enterprises and generated employment, often with PABRA support.

Cultivating beans appears to be a wealth-neutral agricultural activity. Farmers in several countries, particularly Rwanda, reported that poor or very poor members of the community were as likely to adopt the new varieties as better off farmers. Many adopters are women, who have seen their incomes rise substantially. To reduce the risk that men will try to appropriate the income gains by taking over what is traditionally a women's crop, PABRA has sought to build the capacity of women's groups and associated service providers in starting and running agro-enterprises. Other social benefits realized by participating bean farmers include exposure to new services providers (i.e., credit and input supplies) as well as new information on health and nutrition.

Beans are highly vulnerable to climatic stresses, especially drought. During the past few years, PABRA partners have developed varieties that combine drought tolerance with other desirable traits. These efforts must continue and intensify, producing new varieties screened and tested for early dissemination and release.

PABRA's second decade will be even more challenging than its first. PABRA's focus on seed-based technologies has been effective. Plant breeding, as the source of these technologies, will continue to be a key activity. The fight against pests and diseases must intensify and broaden, because new threats constantly arise. Besides bean root rot, other critical diseases that need tackling include angular leaf spot, anthracnose, leaf rust, common bacterial blight, and bean mosaic virus. Priority pests include bean stem maggots, aphids, and cutworms. In addition, there will be continued focus on low soil fertility and drought. Selection and breeding for resistance or tolerance will, as now, be combined with IPDM approaches that maximize the gains to farmer and ecosystem health. Besides addressing drought, PABRA is extending traditional bean areas to the hot and humid areas of West Africa, where consumer demand and prices are high (Kimani 2006).

#### *Recommendations for Practitioners*

To reach marginalized farmers, efforts to disseminate seed-based and other technologies must be reinforced. Adoption patterns reveal three priorities: (a) dissemination efforts in areas that have been neglected or bypassed, (b) a greater number of varieties offered to allow greater resilience of production and household food security, and (c) continued development and adaptation of knowledge-based technologies (i.e., IPDM) that typically lag behind those of seeds.

PABRA researchers are striving to improve the nutritional content of beans. As part of the HarvestPlus initiative, researchers are working to develop biofortified beans, focusing on iron and zinc in agronomically superior varieties. Efforts to enhance the contribution of beans, particularly for those affected by the continuing spread of HIV/AIDS, require coordination with organization outside the agricultural sectors. Besides developing and disseminating new varieties rich in minerals, promotional campaigns will need to involve community-based health and nutrition workers.

As African farmers produce more and better beans, they will need to participate in markets. Ensuring that beans remain a profitable option requires investments in cost-effective processing options and efforts to open up new regional markets. If prices for beans and other cash crops can be sustained, farmers may likely be more willing to invest in their farms, especially in the fertility of their soils.

As Ward et al (2007) report, the PABRA approach reaches well beyond the innovators. Farmers in Kisii, Kenya cited benefits from the adoption of improved bean technology as increased amount of household food, household income, availability of food all year round, improvements in family health and relationship with other farmers, and increase in the income controlled by women. Data from Uganda show increasing involvement in local trade of beans as the farmers move beyond subsistence. Farmers also started actively to explore other technologies. For example, farmers in

northern Tanzania experimented with a locally available phosphate based fertiliser (Minjingu mazao) on the bean crop. But they quickly went on to test the fertiliser on other crops, such as maize and vegetables, and modified their fertiliser use on these crops also.

Encouraged by their experiences with beans, farmers started actively to seek improved services (such as quality seed, markets, credit, improved livestock, fertilisers, tree nurseries, irrigation facilities, soil and water conservation methods) (Blackie and Ward 2005); raising these issues openly with local officials and visitors - something previously they lacked the confidence to do. Local officials, community leaders, NGOs and politicians through the enhanced participation gain information for local planning and use the research groups as an important and dynamic component in the local innovation system . . Government ministries (of Agriculture, Livestock, Health, Education and Marketing). District authorities in Malawi, Tanzania, Kenya and Uganda use the farmers groups to develop and implement community based project proposals.

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## Selected Readings

- BBC NEWS | Science/Nature | "Barren future" for Africa's Soil. <http://news.bbc.co.uk/2/hi/science/nature/4860694.stm>
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## **Web Resources**

<http://www.ciat.cgiar.org/africa/pdf/highlight34.pdf>

Centro Internacional de Agricultura Tropical. [www.ciat.cgiar.org/](http://www.ciat.cgiar.org/)

Harvest Plus. <http://www.harvestplus.org/pdfs/beans.pdf>

This Note was prepared by Douglas White, CIAT and PARBA.

## **Investment Note: Carbon Earnings: Making Sustainable Land Management a Good Deal for Landowners**

### *Summary*

100 years ago, the Atlantic Savanna of northern Colombia was mostly covered in forest. Now cattle ranches dominate the landscape. Trees are few. At some times during the year, the landscape is lush with grasses, but during the dry months, it is brown and dusty (Figure 1). Cattle are a major component of the region's economy. While researchers have developed silvopastoral systems that generate large productivity increases, the short term costs are significant and certain – the long term returns are seen as uncertain. The initial establishment costs of improved silvopastoral systems scares off smallholders and wealthy farmers alike.

Many tropical countries offer an optimal growing climate to capture atmospheric carbon cost-effectively. Carbon trades can change the economics of establishing silvopastoral systems significantly – but moving from concept to implementation is not straightforward.. To get money from governments and industry reliably into the hands of farmers and ranchers planning and coordination involving many actors. Nevertheless, the carbon market mechanism facilitated by the BioCarbon Fund of World Bank has enabled 2,500 ha of degraded land in Córdoba to be reforested or converted into silvopastoral systems. The programme directly addresses the problem of annual cash flow needs which prevent smallholder farmers from transitioning their lands to forest.

Selection of key partner organizations and staff facilitates the process. CIAT, as an institution had valuable networks and connections that ranged from the World Bank to national and departmental organizations. Importantly also, CIAT had detailed knowledge of the technologies that could be employed in carbon capture, thus being able to provide the core data necessary to develop a credible implementation plan.

### *Key Sustainable Land Management Issues*

One hundred years ago, the Atlantic Savanna of northern Colombia was mostly covered in forest. At present, cattle ranches dominate the landscape. Trees are few. At some times during the year, the landscape is lush with grasses, but during the dry months, it is brown and dusty (figure 3.13). Cattle endure the conditions and remain a powerful engine of the region's economy. CIAT did something new in 2005. In fact, it was new for all four organizations involved, including the Colombian Agriculture Research Center (CORPOICA), the Conservation Agency of Córdoba department (CVS), and the World Bank. This investment note describes how these partners enabled farmers to make SLM investment with the financial support from carbon markets.

In other words, resource use has changed. Water and soil resources produce fewer trees and more cattle. To some, this land conversion is a common process. Forests become pastures and agricultural fields. Nevertheless, good land productivity does not last. In many areas of Córdoba, cattle production is low -- less than one head per hectare. Land uses reflect economic activity. Pastures cover 61 percent of Córdoba, commercial forest 25 percent, and natural forests 3 percent (Cruz and Franco 2006).

In Cordoba, some ranches are large. Many of them belong to wealthy absentee owners who may not care about productivity. Earnings from land come from its rapidly increasing price. Perhaps personal status is gained at social events upon mentioning the ranch.

Farm laborers and smallholders are the other side of Córdoba. Although both the wealthy and less-wealthy earn little from their land, a stark social contrast is an underlying cause for civil conflict. The

region is known for its guerilla and paramilitary and improvements in land productivity and local livelihoods could help relieve the tension.

**Figure 3.13 Dry Season Grazing in Córdoba, Colombia**



Source: CIAT

#### *Lessons Learned from Past Experiences*

Researchers have advanced ways to improve land productivity. However, only some of the technologies are attractive enough to adopt. Farmers are more likely to accept relatively simple technologies such as new grasses because benefits are seen quickly. CIAT and CORPOICA have a long history of generating productivity increases of pastures. Researchers select the best grasses and improve their performance with sophisticated breeding techniques.

Farmers do not readily accept complicated technologies. Researchers have developed silvopastoral systems that generate large productivity increases (Figure 3.14; Cajas and Sinclair, 1999). In addition to improved grasses, such systems include bushes and trees that diversify production. In the long term, more cattle can be produced per hectare with increased profits. But the short term costs are significant and certain – the long term returns are seen as uncertain. Nevertheless, the initial establishment cost is a constraint when local credit is unavailable.



**Figure 3.14 Silvopastoral System. Cattle browsing leguminous fodder shrubs.**



Source: CIAT

*Opportunities for Sustainable Land Management: Products and Services*

Carbon, typically an insulator of electric current, has become a conductor and spark. Because of the need to compensate their emissions, industrialized countries want to purchase carbon. Many tropical countries offer an optimal growing climate to capture atmospheric carbon cost-effectively. Hence, a new market for carbon connects demand and supply. Carbon trades provide enough money incentive to convince numerous landowners to change their land management practices. Now, a barrier to establishing silvopastoral systems has been removed.

In principle, this can change the economics of establishing silvopastoral systems significantly – but moving from concept to implementation is not straightforward. To get money from governments and industry reliably into the hands of farmers and ranchers planning and coordination involving many actors (Robbins 2004). Nevertheless, the carbon market mechanism facilitated by the BioCarbon Fund of World Bank enables 2,500 ha of degraded land in Córdoba to be reforested or converted into silvopastoral systems. The BioCarbon Fund of the World Bank acts as a broker for the carbon trades and certifies the Carbon Emission Reductions (CERs). The environmental services and products from these land use changes are many. In addition to carbon storage, the lands will: (a) enhance biodiversity by substituting monospecies land cover by more diverse systems that favor higher faunal and microbial populations; and (b) benefit transboundary migratory fauna (e.g., birds and butterflies). SLM products will also increase. Local residents will benefit from the creation of



direct employment for workers that will tend tree nurseries, plant seedlings, and fence and maintain the silvopastoral improvements and reforestation initiatives.

Job generation is a critical challenge for the region. Unemployment is approximately 22 percent. By demonstrating the potential and actual value of higher productivity land, the project can start to convince others, thereby energizing the regional economy and potentially reduce civil strife.

#### *Rationale for Investment*

Benefits and beneficiaries are many. Landowners will increase income with these profitable land uses. CVS will recover their initial investment in helping to establish the land use systems. More farmers can benefit from expanded environmental conservation efforts. Project participants include three distinct groups: (a) smallholder farmers of indigenous descent will establish silvopastoral, (b) smallholder farmers will set up rubber plantations, and (c) medium-scale farmers will reforest larger tracts of land. The priority of capturing large amounts carbon requires the inclusion of reforestation projects. Annual cash flow needs prevent smallholder farmers from transitioning their lands to forest.

#### *Recommendations for Practitioners*

To implement a complex initiative of this nature, a range of expertise is required: agronomy, economics, forestry, project development, management, negotiation – to name a few. Being able to speak the same language is important, not just Spanish, but across the areas of expertise. Selection of key partner organizations and staff facilitates the process. The extensive network of CIAT facilitated our experience with BioCarbon. CIAT, as an institution had valuable networks and connections that ranged from the World Bank to national and departmental organizations. Importantly also, CIAT had detailed knowledge of the technologies that could be employed in carbon capture, thus being able to provide the core data necessary to develop a credible implementation plan.

BioCarbon does not provide funds to initiate project investments. Another entity must provide financing based on the future value of the CERs. CVS provided the financing with the expectation of recovering part of their investment through the value of the CERs. Some banks finance such investments but not yet in Colombia. Many steps are required to reach approval of a project.

To advance the project, numerous other steps were required by local partners:

1. Disseminate project objectives and economic benefits to local farmers.
2. Meet with eligible local farmers to determine levels of interest, the administrative and legal capacities of farmer associations, discuss participant obligations and expected benefits.
3. Negotiate with interested farmers on amount of land entering the program with respect to needs and capacities.
4. Select SLM alternatives that best fulfill the different participant's needs and expectations.

CIAT had both the networks and the information necessary to facilitate these steps.

Partnerships between conservation, scientific, and funding organizations are crucial for designing and implementing a project that generates social benefits from environmental services provision. Partnerships are viable when certain factors converge: (a) degraded lands, (b) knowledge of sustainable and profitable land management alternatives, such as silvopastoral systems and forest systems, (c) local interest in such SLM alternatives, (d) willing investors, (e) expertise in greenhouse gas balances and socioeconomic assessment of land uses, (f) organized farmers with administrative,

legal, and leadership capacities. With these factors and conditions in place, perhaps this BioCarbon effort will enhance both environmental and social benefits for the people of Córdoba, Colombia.

Would we do it again? No, but yes. For many, the time and costs of learning the complicated process soon overwhelmed the excitement of entering a new globally-important development and conservation theme. Nevertheless, with the investment already made and experienced gained, future BioCarbon will be cost-effective.

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## Web Resources

<http://carbonfinance.org/Router.cfm?Page=BioCF>

[www.ciat.cgiar.org/](http://www.ciat.cgiar.org/)

[www.corpoica.org.co/](http://www.corpoica.org.co/)

<http://www.cvs.gov.co/index.htm>

[http://cdm.unfccc.int/methodologies/ARmethodologies/approved\\_ar.html](http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html)

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## **Innovative Activity Profile: Fodder Shrubs for Improving Livestock Productivity and Sustainable Land Management in East Africa**

### *Summary*

In East Africa, zero-grazing systems are the most common smallholder dairy system; farmers cut and carry feed to their confined dairy cows. Fodder legumes have been tested for over 50 years as protein supplements - but with little adoption. Fodder shrubs are a low-cost, easy-to-produce protein source that could at the same time contribute to sustainable land management. They are highly attractive to farmers because they require little or no cash, nor do they require farmers to take land out of food or other crops. But the technology is “knowledge intensive” and requires new skills on the part of the farmer.

The spread of fodder shrubs has been substantial and, by 2006 (about 10 years after dissemination began in earnest) were contributing about \$ 3.8 million per year to farmer incomes across East Africa. Critical to the expansion were extension approaches involving dissemination facilitators (specialists who promote the use of fodder shrubs among extension providers and support them with training, information and gaining access to seed), farmer to farmer dissemination, the involvement of large non-governmental organization (NGO) promoters, facilitating seed flows (seed availability was a key constraint in many areas), and civil society campaigns involving a broader set of partners than just farmers and extension providers.

### *Project objective*

The low quality and quantity of feed resources is the greatest constraint to improving the productivity of livestock in sub-Saharan Africa (Winrock International 1992). Dairy production is increasing rapidly in the highlands of East Africa, which hosts roughly three million dairy farmers, including some two million in Kenya alone (Smallholder Dairy Project 2006). Milk demand is concentrated in towns and cities and dairy production has grown rapidly around these, to take advantage of low marketing costs. But farm sizes are also generally small in these peri urban areas, exacerbating feed constraints. Land degradation is also a pervasive problem; most of the land is sloping and soil erosion reduces crop productivity.

Zero-grazing systems are the most common smallholder dairy system; farmers cut and carry feed to their confined dairy cows. Napier grass is the basal feed of choice but its protein content is too low to sustain adequate milk yields. Manufactured dairy meal is available in most areas but few small farmers use it, due to its high price. Fodder legumes have been tested in East Africa for over 50 years as protein supplements - but there are few cases of widespread adoption, especially in the smallholder sector. The objective of introducing fodder shrubs in East Africa was to provide a low-cost, easy-to-produce protein source that could at the same time contribute to sustainable land management.

### *Study area description*

The highlands of East Africa extend across central and western Kenya, westward to Uganda and Rwanda, and to the south in parts of Northern Tanzania. Altitudes range from 1000 m to 2200 m. Rainfall occurs in two seasons, March–June and October–December, and averages 1200 mm to 1500 mm annually. Soils, primarily Nitosols, are deep and of moderate to high fertility. Population density is high, ranging from 300 to over 1,000 persons/km<sup>2</sup>. In central Kenya, which has the region's highest numbers and density of dairy cows, farm size averages one to two hectares. Most farmers have title to their land, and thus their tenure is relatively secure. The main crops are coffee, produced

for cash, and maize and beans, produced for food. Most farmers also grow Napier grass (*Pennisetum purpureum*) for feeding their dairy cows and they crop their fields continuously because of the shortage of land. About 80 percent have improved dairy cows. The typical family has 1.7 cows, kept in zero- or minimum-grazing systems. Milk yields average about 8 kg/cow/day and production is for both home consumption and sale. Dairy goats, which are particularly suited to poorer households, are a rapidly growing enterprise (Murithi 1998; Staal *et al.* 2002).

The main feed source for dairy cows in Kenya is Napier grass, supplemented during the dry season with crop residues (such as maize and bean stover, and banana leaves and pseudostems), and indigenous fodder shrubs. Commercial dairy meal (16 percent crude protein) is purchased by very few farmers. Dairy meal use has declined in recent years as farmers complain that the price ratio between dairy meal and milk is unfavourable and that they lack cash to buy the meal. Many also suspect the nutritive value of dairy meal, in part because of scandals concerning fraudulent maize seed and agrochemicals sold to farmers (Murithi 1998; Staal *et al.* 2002; Franzel *et al.* 2003).

Smallholder dairy systems in Uganda, northern Tanzania and Rwanda are similar to those in Kenya but the density of dairy farmers and cows is generally lower, as is government extension support and private sector marketing infrastructure

#### *Presentation of innovation*

Fodder shrubs are highly attractive to farmers because they require little or no cash, nor do they require farmers to take land out of food or other crops. The only inputs required are the initial seed and minimal amounts of labor; which farmers are usually willing to provide. But like many agroforestry and natural resource management practices, fodder shrubs are “knowledge intensive” and require considerable skills that most farmers do not have. These include raising seedlings in a nursery, pruning trees, and the best ways feeding the fodder to livestock. These skills are difficult to acquiring; as is, at times, the necessary seed. Thus the technology does not spread easily.

Farmers prefer planting fodder shrubs in the following locations and arrangements:

- in hedges around the farm compound.
- in hedges along contour bunds and terrace edges on sloping land. The shrubs thus help conserve soil and, when kept well pruned, have little effect on adjacent crops.
- in lines with Napier grass. Results from intercropping experiments show that introducing calliandra into Napier grass has little effect on the grass yields (Nyaata *et al.* 1998).
- in lines between upper-storey trees. Many farmers plant *Grevillea robusta*, a tree useful for timber and firewood along their boundaries. Fodder shrubs may be planted between the trees in the same line (NARP 1993).

Seeds are planted in nurseries and then transplanted on the farm at the onset of the rains, after about three months in the nursery. Experiments on seedling production have confirmed that the seedlings may be grown ‘bare-root’; raised in seedbeds rather than by the more expensive, laborious method of raising them in polythene pots (O’Neill *et al.* 1997).

The shrubs are first pruned for fodder 9 to 12 months after transplanting, and pruning is carried out four or five times per year (Roothaert *et al.* 1998). Leafy biomass yields per year rise if the shrubs are pruned less frequently and allowed to grow taller – but, as this happens, competition from the shrubs means that adjacent crop yields are negatively affected (ICRAF 1992). The most productive compromise is probably in the range of four to six prunings per year at 0.6 to 1 m cutting height.

This yields, under farmers' conditions, roughly 1.5 kg dry matter (4.5 kg fresh biomass) per tree per year planted at a spacing of two to three trees per metre in hedges. Thus, a farmer needs about 500 shrubs to feed a cow throughout the year at a rate of 2 kg dry (6 kg fresh) matter per day, providing about 0.6 kg crude protein. This amount provides an effective protein supplement to the basal feed of Napier grass and crop residues for increased milk production. A typical farm of 1.5 ha could easily accommodate 500 shrubs without replacing any existing crops (Paterson *et al.* 1998)<sup>2</sup>.

On-farm feeding trials have confirmed the effectiveness of calliandra as a supplement to the basal diet. Two kilograms of dry calliandra (24 percent crude protein and digestibility of 60 percent when fed fresh) have about the same amount of digestible protein as 2 kg dairy meal (16 percent crude protein and 80 percent digestibility); each increases milk production by about 1.5 kg under farm conditions. But, the response is variable, depending on such factors as the health of the cow and the quantity and quality of the basal feed (Paterson *et al.* 1998).

Since calliandra was introduced in the mid-1990s, several other shrub species have also been tested and disseminated (Wambugu *et al.*, 2006). In Kenya, *Leucaena trichandra*, an exotic species, *Morus alba* (mulberry, a naturalized species), and *Sesbania sesban* (an indigenous species) are widely grown but are not as commonly as calliandra. In Rwanda, calliandra and *Leucaena diversifolia*, also an exotic, are the most common fodder shrubs. In Uganda, these same two shrubs, and *sesbania*, are widely grown. In northern Tanzania, calliandra and *Leucaena leucocephala* are the most widely used species.

#### *Benefits and impact of the activity*

The main benefit to using fodder shrubs is increased milk production. In an economic analysis from Kenya in 2006, we compared the value of increased milk production with the costs of establishing a nursery, raising 500 calliandra seedlings, transplanting them on the farm, and harvesting them for feed. In the first year, the farmer spends about \$13 establishing the nursery, raising the seedlings, and transplanting them. About \$1.70 of this amount is in cash for seed and the rest is in labor. Beginning in the 2nd year, when the farmer starts harvesting the shrubs, the 500 calliandra shrubs increase net household income by about US\$95-122 a year, depending on the location. The main causes of variation in income increases across location were differences in milk prices. The analysis does not take into account several other benefits of fodder shrubs. First, they increase the butterfat content of milk (in the farmers' terms, its 'creaminess' and 'thickness'). Second, the extra nutrients that the shrubs provide may improve the cow's health and shorten the calving interval. Finally, farmers can also benefit from harvesting and selling seeds.

Fodder shrubs also make important contributions to sustainable land management, which are not taken into account in the above analysis:

- Nitrogen fixation. Five of the six species fix nitrogen from the atmosphere and thus contribute to improving soil fertility. As long as these species are grown in 1-metre high hedges, they do not compete with crops grown next to them.
- Increased quantity and quality of manure. Most fodder species are high in tannins, which bind protein and increase the levels of nitrogen in manure. The increase in quantity and quality of manure helps increase soil fertility.

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<sup>2</sup> For example, such a farm would typically have available about 500 metres of perimeter and several hundred metres in each of three other niches: along terrace edges or bunds, along internal field and homestead boundaries, and in Napier grass plots. With the recommended spacing, the needed 500 trees would only occupy 250 metres of this available space.

- Soil erosion control. Fodder shrubs are planted along the contour, reducing soil erosion. The shrubs are particularly effective when combined with grasses.
- Substitutes for products obtained from forests: Most of the shrub species provide firewood, fencing and stakes, reducing the need to source these off the farm and deplete woodlands.

In the Kabale area of western Uganda, over 70 percent of farmers mentioned fencing, firewood, soil fertility improvement, and stakes as important benefits of fodder shrubs (Mawanda, 2004). In central Kenya, over 30 percent mentioned firewood, soil fertility improvement and improvement in animal health (Koech, 2005).

The spread of fodder shrubs has been substantial. By 2006, about 10 years after dissemination began in earnest, we found that 224 organizations across Kenya, Uganda, Rwanda, and northern Tanzania were promoting fodder shrubs and that over 200,000 farmers had planted them (Table 1). Numbers of shrubs average 71 to 236 per farmer depending on the country. Note, however, this is still well below the 500 shrubs needed to feed a single dairy cow. The explanation is that many farmers adopt incrementally (they plant some want to see how the shrubs perform before adding more), and others “partially adopt” (they apply several different strategies for providing protein supplements - herbaceous legumes, dairy meal, etc. - in order to manage better the risks of relying on a single strategy). The numbers of shrubs per farmer are higher in countries such as Uganda, where NGOs promote fodder shrubs and are lower in countries such as Kenya, where farmer-to-farmer dissemination is the main cause of the spread.

Fodder shrubs are currently contributing about \$ 3.8 million per year to farmer incomes across East Africa. The potential, if all farmers were to adopt, is over \$200 million per year.

#### *Lessons learned*

Representatives of 70 organizations promoting fodder shrubs were interviewed and asked to name the most important factor explaining their achievements in disseminating fodder shrubs. The most important factor, with a mean score of 4.1 on a scale of 0 to 5, was that fodder shrubs met the needs of farmers (Franzel et al., 2007). Other key factors were that the fodder shrubs were profitable, that effective extension approaches were used, and that partnerships with other organizations facilitated success. Less important factors included long-term commitment by key players, farmers’ commercial orientation, farmer skill levels, availability of training materials and backstopping from research. Many of the reasons for the spread have to do with the technology itself, its attractiveness to farmers, and with the socio-economic environment and, in particular, the rapid growth of the smallholder dairy industry in the region. Franzel et al. (2007) found that five extension approaches were critical for the spread of the practice:

a. *Dissemination facilitators* are extension specialists who promote the use of fodder shrubs among extension providers and support them with training, information and gaining access to seed. Dissemination facilitators were employed by international organizations such as ICRAF or national agricultural research institutes such as the National Agricultural Research Organization of Uganda. The dissemination facilitators proved to be highly effective. In central Kenya, for example, over a two-year period, a dissemination facilitator assisted 22 organizations and 150 farmer groups comprising 2,600 farmers to establish 250 nurseries and plant over 1,000,000 fodder shrubs (Wambugu *et al.* 2001)

b. *Farmer to farmer dissemination.* Survey results showed that farmers played a critical role in disseminating seed and information to other farmers. A survey of 94 farmers in central Kenya, randomly selected from farmers who had planted fodder shrubs three years before, revealed that 57 percent had given out planting material (seeds or seedlings) and information to other farmers. On average, those giving out planting material gave to 6.3 other farmers. But what was most astounding was that 5 percent of the farmers accounted for 66 percent of all dissemination. These 'master disseminators' did not differ from other farmers in any appreciable way – they included both men and women, and had a range of different ages, levels of education, and farm size. Farmers receiving planting material from other farmers had high rates of success in planting; about 75 percent were found to have fodder shrubs.

c. *Large non-governmental organization (NGO) promoters.* In Uganda and Rwanda, a few large, international NGOs facilitated the dissemination of fodder shrubs to many thousands of farmers, accounting for over half of farmers planting in the two countries. Large NGOs were also important in facilitating the spread of the practice in Kenya and Tanzania. Some of the NGOs employed hundreds of extension staff and thus had significant reach. Many were promoting dairy production and wanted to ensure that their farmers had sufficient feed for their cows. Others were promoting sustainable land management and helped farmers plant shrubs for a range of purposes, soil erosion control, firewood and fodder.

d. *Facilitating seed flows.* Seed availability was a key constraint in many areas. Calliandra, the main species, produces relatively little seed and farmers need to be trained to collect, maintain and treat it before planting. An assessment of the seed market chain found that private seed vendors in western Kenya were effective in providing seed to big institutional suppliers, such as NGOs, but were ineffective in reaching farmers, particularly in central Kenya where the greatest number of potential adopters were. Following the study, ICRAF and its partners assisted seed vendors in central Kenya to form an association which forged links with seed providers in western Kenya, and to package seeds in small packets for sale to farmers in central Kenya (Franzel 2007). Over an eight month period in 2006, 43 seed vendors sold over 2.3 tons of seed, sufficient for over 40,000 farmers. A thriving private seed market is a key to sustainable growth in the adoption of fodder shrubs.

e. *Civil society campaigns.* A much broader set of partners than just farmers and extension providers can add significant value in promoting a new technology such as fodder shrubs. The SCALE (System-wide Collaborative Action for Livelihoods and the Environment) methodology brings civil society stakeholders together to plan and implement campaigns to promote new practices (AED 2006). By engaging with a wide range of stakeholders, representing all aspects of a given system (in this case, dairy production), SCALE generates change across many levels and sectors of society, using a combination of different social change methodologies including advocacy, mass communication and social mobilisation. Our experience with the SCALE approach in central Kenya highlights the effectiveness of civil society campaigns as complements to more conventional extension programs. Religious leaders, the media (radio, TV, the press), private input suppliers, local government administrators, and dairy companies each have a critical role to play in sensitizing and training farmers about new practices such as fodder shrubs.

#### *Issues for wider application*

This paper documents the substantial progress that has been made in promoting fodder shrubs in East Africa. But the 200,000 farmers planting them represent less than 10 percent of dairy farmers in the region. Because of the knowledge-intensive nature of the technology, it will not spread easily on its own and thus requires outside facilitation. Considerable investments are still required to reach the



other dairy farmers and sustain the uptake process. With formal extension systems in decline throughout Africa, more efforts are needed to develop other approaches for spreading the use of fodder shrubs. This paper documented four dissemination approaches that are particularly effective and where greater investment in research and development is needed:

- Dissemination facilitators to support organizations promoting fodder shrubs offer a high return to investment. These facilitators do not train farmers; rather they train trainers and therefore have a high multiplicative effect in promoting new practices.
- Mechanisms are needed to promote farmer to farmer dissemination and, in particular, ‘master disseminators’ who spread new practices in their communities. Research is needed to determine how best to select them and how to support them.. Is it worthwhile to assist them with transportation (e.g., bicycles) or train them in the use of fodder shrub technologies or extension methods? Can they be assisted to earn cash from providing extension services, either in exchange for the information they provide or through selling inputs such as fodder shrub seeds and seedlings?
- Seed vendors face an array of constraints: NGOs giving out free seed and undercutting their business, government seed centers selling seed to institutional buyers at subsidized prices, and government services demanding licensing fees. Efforts in Kenya have been successful in helping seed vendors to organize and increase their sales and reach. More efforts are needed to support them, by linking them with institutional buyers and lobbying governments for policy reforms to provide them with a level playing field. Efforts are also needed to help seed vendors in other countries to emerge and to organize themselves.
- Civil society campaigns offer great promise for both sensitizing communities about new practices and training farmers in their use. Key questions that research could address concern the scope of the campaign (e.g., fodder shrubs, enriched feeds, or dairy production), the balance between sensitization and training, and the relative importance and effectiveness of involving different types of stakeholders, e.g., the media, religious leaders, and dairy companies.

Finally, investments are needed in two other key areas to sustain progress in fodder shrub adoption and impact, especially in regard to sustainable land management:

- Improved species diversification: The range of species currently available to farmers should be expanded to include more indigenous shrubs, in order to reduce the risk of pests and diseases and promote local biodiversity. The most widely planted shrub, calliandra, has numerous qualities that make it attractive: it is easily propagated, it grows fast and withstands frequent pruning, and it does not compete much with adjacent crops. But it is not among the most nutritious of feeds (Hess *et al* 2006); greater efforts are needed to find shrubs that have calliandra’s favorable features and are higher in nutritive quality. Moreover, improved species are needed for marginal environments. Fodder shrub species are currently available for the highlands (1,200 m to 2,000 m) but few are available for higher altitudes or for semi-arid areas.
- More research is needed on the role that fodder shrubs can play in curbing soil erosion. In Rwanda, fodder shrub hedges are used for making ‘progressive terraces,’ which form because soil builds up behind a hedge that stops soil from moving down the hillside. Fodder shrubs are also used to stabilize existing terraces. Policy makers want to know the costs and benefits of using biological means of soil erosion, such as fodder shrubs, as compared to radical terracing, in which manual labor is used to build terraces.

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**Table 3.6 Estimates of Numbers of Farmers Planting Fodder Shrubs in Kenya, Uganda, Rwanda, and Northern Tanzania**

Country	Numbers of organizations promoting fodder shrubs	Numbers of farmers planting according to our records	Rough estimate of additional farmers planting	Total	Numbers of trees per farmer	Notes and sources
Kenya	60	51,645	30,000	81,645	75	Data in records column are from four random sample surveys and reports from 23 organizations, mostly from 2004-05. Data in "rough estimates" column include numbers in areas with fodder shrubs for which we have no data (e.g., Coast, Kisii, and Machakos) and increases in central and eastern provinces since 2003 surveys. Data in records column are from surveys in 2003 and 2005 in which 44 organizations reported on numbers of farmers planting fodder shrubs. Data in "rough estimates" column include numbers in areas we did not include in the survey and 16 organizations that were unable to report on numbers of farmers. Many of the organizations were promoting fodder shrubs primarily for soil conservation. Data in records column are from 14 organizations in Arusha and Kilimanjaro, and estimates of numbers of collectors, planters, processors, and users in Tanga. Data in "rough estimates" are for farmers in Mwanza, Lushoto, and other parts of northern Tanzania where fodder shrubs are promoted. Data in records column are from 11 of the organizations that promoted fodder shrubs 2000-2005. In "rough estimate" column, we estimate that each of the other 44 organizations that bought seed helped 100 farmers to plant. Many of the organizations were promoting fodder shrubs primarily for soil conservation.
Uganda	80	77,369	5,000	82,369	306	
Northern Tanzania	15	17,519	10,000	27,519	99	
Rwanda	69	9,590	4,400	13,990	266	
<b>Total</b>	<b>224</b>	<b>156,123</b>	<b>49,400</b>	<b>205,523</b>	<b>184</b>	

This Profile was prepared by Steven Franzel, Charles Wambugu, Hellen Arimi, and Janet Stewart, ICRAF. Nairobi, Kenya.

Source: Franzel et al. 2007.

### **Section III-C. Rainfed Dry/Cold Farming Systems**

Rainfed dry/cold farming systems cover around 3.5 billion ha. However, rain-fed dry/cold farming systems support a relatively modest agricultural population of 500 million. Approximately 231 million ha is cultivated, of which 18 percent is irrigated. Population density is low with 2.1 people per hectare of cultivated land.

These lower potential systems are generally based on mixed crop-livestock or pastoral activities, merging eventually into sparse and often dispersed systems with very low productivity or potential because of environmental constraints to production. In Africa the main crops are millet and sorghum. In the Middle East and North Africa the system is based on wheat, barley, and a wide variety of pulses and oil crops among others. Crop-livestock integration is important, especially when cattle are fertilizing fields while browsing on cereal straw after the harvest. In some of the systems, small-scale irrigation opportunities exist, allowing pastoralists to supplement their livelihoods in diet and income. New irrigated areas are developed in MNA through new drilling and pumping technologies. Market development is limited.

The main source of vulnerability is the great climatic variability and drought, leading to crop failure, weak animals, and the distress sale of assets. Population density is modest however pressure on the limited amount of cultivated land is very high. Overgrazing is common resulting in low livestock productivity, environmental damage, and desertification. Poverty is extensive, often severe, and accentuated by drought.

#### *Potentials for Poverty Reduction and Agricultural Growth*

The potential for poverty reduction and for agricultural growth is modest. It has some similar characteristics with the highland rain-fed systems, because of the low agricultural potential and the poor marketing infrastructure. Exit from agriculture has been judged to be the most important strategy for poverty reduction, followed by increase in off-farm income and diversification.

Diversification will be based on livestock, on irrigation where possible, and on improved land management that allows better resisting climate variability. Animal productivity can be improved through better use of crop residues and by-products, promoting locally adapted breeds, control of epizootic diseases, and improving village poultry production. Support to small-scale private livestock trading has some potential. Hides and skins, for instance, are often undervalued products. There is limited potential for agricultural development except where irrigation can be developed and where water resources are not overexploited. The development of higher value crops such as fruits and vegetables is restrained because of rainfall uncertainties and relatively poor market linkages. Thus, key priority will be to reduce the likelihood of crop failure in drought years through improved land and water management, multiplication of palatable, drought-resistant, and early maturing crop varieties. The regeneration of forests and natural vegetation is necessary for sustainable fuelwood supply and for soil fertility management.

## **Investment Note: Integrating Land and Water Management in Smallholder Livestock Systems in Sub-Sahara Africa**

### *Summary*

Livestock perform multiple functions in the global economy and household level livelihoods e.g. food, economic security, enhanced crop production, generation cash income and produce value added goods which can have multiplier effects and create a need for services. With increasing population pressure, farmers and governments are striving to produce more food using the existing land based resources. The result is a reduction in the land available for pasture and grazing land with restrictions on the movement of animals. Increases in livestock productions and productivity can be coupled with environmentally sustainability if timely interventions are adopted. Without a clear strategy for the closer integration of crops and livestock, the outcome is inevitably widespread environmental degradation.

ILRI has identified resource management policy research as a key strategy. This includes establishing trends on how current livestock management affects resource use and conservation in the future, and how changes in government policies affecting the institutions which deal with risk, credit, commodity pricing and macroeconomic policies which affect resource use and the environment.

### *Key Sustainable Land Management Issues*

Livestock perform multiple functions in the global economy and household level livelihoods (e.g., food, economic security, enhanced crop production, generation cash income and produce value added goods which can have multiplier effects and create a need for services) Sere and Steinfeld 1996.

With increasing population pressure, farmers and governments are striving to produce more food using the existing land-based resources. In some regions such as Africa and Latin America, food production is occurring via expansion of crop lands into more marginal areas. In south Asia and Southeast Asia, the trend is for a rapid expansion of urban areas into former agricultural lands. In both cases, however, the net result is a reduction in the land available for pasture and grazing land with restrictions on the movement of animals. There are two major ways of increasing livestock productivity in the various production systems, either through intensification of systems using high input production and management principles, including improved breeds, improved animal health, and cut and carry industrial systems, or through more intensively managed ranching systems. The increase in livestock productions and productivity could be coupled with environmentally sustainability if timely interventions are adopted.

Land management invariably implies nutrient, water and vegetation management, and its sustainable management demands integrated technological, policy and institutional interventions. Increase in crop yield or pasture through improved agronomic practices (e.g. optimum nutrient inputs) could enhance water use efficiency while the nutrient out flux through harvested products (e.g. livestock feeding on residues) could be high.

This paper does not review the available literature on livestock-environment issues but rather uses selected case studies involving on livestock–water and livestock-land interaction in Sub Saharan

Africa. These cases are used to indicate potential interventions that could help reduce the degradation of land and water resources in small holder livestock systems.

Globally, livestock systems cover about 3.4 billion hectares of grazing land (Sere and Steinfeld, 1996) and use feed from about 25 percent of the crop land globally. In 1996, about 442,884,000 Mt of dry matter was consumed to provide the meat and milk demanded by the world markets (de Haan et al. 1997). In the future, even more dry matter will be needed as the demand for meat and milk increases with growing urbanization, human population growth and income increases. For example in Africa, it is predicted that ruminant population will increase from 279 to 409 million TLU from 2000 to 2020 (about half of the rangelands and a third of the mixed rain-fed production systems are in SSA) (Peden et al. 2007).

Livestock production systems vary greatly across the world as do the management and the relative importance of livestock products and services. Accordingly, various combinations of production systems have evolved in different part of the world as the result of spatial and temporal diversity in climate; population density, economic opportunities and cultural practices (Stangel, 1993). But the typical sequence is that as populations rise, cropping activities expand, fallow periods formerly used to restore soil fertility are no longer possible, and, concurrently, cropping takes over marginal/fallow lands previously used for livestock grazing. Without a clear strategy for the closer integration of crops and livestock, the outcome is inevitably widespread environmental degradation (Tarawali et al. 2001).

While not entirely distinct from each other, four stages of livestock intensification processes have been observed (McIntire, 1992; Ehui et al. 2003). These stages also also dictate the positive or negative relationships between livestock- and land-based resources.

In the first stage, at low population density and abundance of land, crop and livestock activities are extensive and specialized. There is limited interaction between crop-livestock producers and pastoralists. In this case, the environmental impact of livestock on land management could be positive, even in area where the resource base is marginal. Well managed livestock will do better than crops in these marginal areas.

In the second stage, agriculture intensifies due to population growth and changes in market structures. These are typical of mixed crop livestock systems of SSA whereby the two components are complementary (in some cases, however, competition for land based resources between livestock and crop enterprises can be found). This type of intense integrated crop-livestock interactions occurs in systems like the dry savannah of West Africa (Tarawli et al. 2001).

In the third stage, both agriculture and livestock production intensifies. Livestock producers use more crops to produce meat and milk; crop farmers need draught power and manure to maintain their intensified cropping systems.. Unless market conditions attract external inputs to restore resource balances and minimize depletion of land-based resources by either farmers or livestock producers, the long term consequence is nutrient mining and degradation of water resources.

In the fourth stage, where markets and improved technologies accompany population growth and increased labor prices, the system will increasingly depend on external inputs, thereby developing more profitable specialized livestock enterprises. But where markets are weak (as in much of SSA), with increasing population pressure and declining farm size, even the traditional grazing areas including steep slopes and communal lands become converted to crop fields (though the return for

investment is relatively low) forcing ,livestock systems to use even more marginal areas. On the other hand, in areas where market access for livestock products is appealing, farmers integrated multipurpose forages both with feed value and soil fertility restoration.

In general, the different livestock production systems developed in various parts of SSA are highly influenced by the way how livestock interacts with water and nutrient resources. The attempts to sustain the land resource base also vary greatly across regions, production systems and economic incentives.

#### *Livestock water and nutrient interactions: Implications for sustainable land management*

Livestock transform poor quality, bulky vegetation to high value products of economic importance and nutritional value (Delgado et al. 1999). They enhance system productivity through nutrient recycling and the provision of manure, supplying draught power for the crop enterprises and providing livelihood options. Draught animals provide about 80 percent of the power used for farming in developing countries. The byproduct of crop production (crop residue) is a principal input for livestock production and the byproduct of livestock (manure and draught power) is a key input for the crop sector. In addition to nutrient recycling, livestock redistribute nutrients between crop land and pasture land or with in the crop land between different plots (feeding livestock on agricultural residues). The complementarities between the livestock and crop sub-components could be much higher than the potential competition between them particularly when well managed livestock can contribute positively to sustainable vegetation cover, improved land management and biodiversity. Moreover, use of livestock may offset the need for petroleum for mechanized agriculture. Although there is a huge potential for a more balanced view of livestock, livelihoods and environment, the potential role of improved livestock management in promoting sustainable land management is neglected in the scientific and development arena.

On the other hand, livestock are most frequently quoted as one of the major drivers of changing land use and soil degradation (Steinfeld et al. 2006) although it may not always be true in well managed mixed crop-livestock systems of Sub Saharan Africa. They could be one of the factors contributing to offsite problems of sedimentation, carbon emissions and affecting climate change, reduced ecosystem function and changes in natural habitats and ultimately leading to loss of genetic stock and biodiversity, particularly in regions where the livestock density is high, carrying capacity is low and the livelihood options are limited. While erosion from crop lands is commonly considered as the major cause of land degradation, at least in the African highlands, Dunstan et al. (2004) indicated that overgrazing is the primary causes of land degradation (49 percent) in the developing world, followed by agricultural activities (24 percent), deforestation (14 percent), and overexploitation of vegetative cover (13 percent). Land fragmentation and limited farm size also contribute to inappropriate livestock management resulting in land degradation. High livestock density may lead to trampling, depletion and pollution of water, the emission of greenhouse gases and the loss of plant and animal genetic resources (de Haan et al. 1997). Livestock production will have also an offsite effect such as the expansion and intensification of cropland to satisfy the increasing demand for feed which in turn may lead to erosion and pollution. In crop livestock systems, where crop production is favoured in resource allocation over livestock, arable lands and fertile corners are commonly allocated for production of food crops while less fertile farm corners, hill sides and degraded outfields are allocated for grazing and pasture. In these systems, there could be a huge pressure of livestock on the land as there is a rare chance for rotation and vegetative recovery. In response to these environmental concerns, various initiatives are being developed and/or proposed to adopt holistic approaches. However, the effects of livestock on dry land



systems is sometimes overstated as changes in rangeland vegetation are often more affected by rainfall, soil type and topography than by grazing (Tarawali et al. 2001). Similarly, grazing could have a positive effect on soil porosity and infiltration rates in the presence of good vegetative cover while the effect could be negative in overgrazed areas (Tarawali et al. 2001).

Livestock provide nutrients to the global agriculture equivalent to USD 800 million per year (Jansen and de Wilt, 1996). Like that of water, nutrient flow between different ecosystem compartments is highly affected by the livestock production system. In the Sahel, Fernandez-Rivera et al. (1995) indicated that if all animals in the sorghum-millet production systems were used for manuring there would be manure input ranging from 300 to 1600 kg/ha. The potential of manure to contribute to sustainable farming in these systems could be influenced by livestock population, spatial location of animals at manuring time, manure excretion per animal, efficiency of manure collection and the availability of feed and land resources (Tarawali et al. 2001). On the other hand, in semi-urban small scale livestock systems of SSA where land is intensively cultivated and animals are stall-fed, manure must be handled, stored, transported, and spread on fields. Most nutrients excreted as urine from stall-fed animals may be lost, either through volatilization or leaching. Thus a move to more stall-feeding of animals could greatly reduce the amount of nutrients recycled back to the rural agricultural systems. In the extensive land use systems, animals graze to satisfy feed requirements and are herded in close proximity to watering points. In these situations, animal manure and urine is highest in non-productive areas such as near watering holes, resting areas and along paths of animal movement. This results in high accumulation of nutrients in these areas and increases the risk of nutrient losses but also contamination of water resources.

The global livestock population requires considerable amounts of water. However, the estimation of these requirements is crude (Peden et al. 2007). Water constitutes about 60-70 percent of animal liveweight. Livestock maintain this level by drinking, consuming moisture laden feed and capturing metabolic water (from intercellular respiration). It is evident also that the major nutrient required for metabolic function of livestock comes from feed and voluntary water intake and the atmosphere (e.g. oxygen). Livestock also lose water and nutrients to the sub-system in the form of evaporation, urine, feces, lactation and respiration. Depending on the scale these losses could be inputs for other non-livestock systems components as organic fertilizers.

When thinking about livestock and water, most people visualize the direct consumption of drinking water. Evidences suggest that voluntary water intake ranges between 25-50 liter TLU-1 day-1 (Peden et al. 2007). This volume varies greatly by species and breeds, ambient temperature, water quality, levels and water content of feed and animal activities. Volume wise, the most important interaction of water and livestock is through evapo-transpiration processes in producing animal feed. In the tropics, animals usually consume (kg DM/day) between 1.5 and 3.5 percent of their body weight depending on the quality of the diet, feed availability, environmental conditions and other factors. Taking about 0.5kg m<sup>-3</sup> of range land water productivity, water required to produce maintenance feed for one Tropical Livestock Unit (TLU)<sup>3</sup> is 100 times more than the water required for drinking. Of these, less than half of the plant material is eaten by animals and about half of what is eaten is returned to the soil as manure (if the animals are in pasture land). Thus only about 25 percent of pasture could go to animals and the rest could support ecosystem services.

In general, farming is under a huge pressure to produce more crop and animal products per units of water and nutrient investment. Livestock sub-systems, which strongly interact with crop and other

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<sup>3</sup> A TLU is equivalent to 250 kg live weight.

system components across fields, farms, and landscapes should be efficient users of resources if the food demand by the growing population is to be satisfied and the environmental services are sustained. Therefore, there is a need to adopt integrated systems approach, which minimize competition for land-based resources between different system sub-components, and introduce interventions that would create win-win situations for enhancing livestock water and nutrients productivity at various scales.

#### *Lessons learned from past experiences*

Water productivity describes the production of more economic agricultural produces per unit of water, expressed in terms of product per units of evapotranspiration (Rockstoem et al. 2003). Peden et al., (2007) suggested the following four major strategies to enhance livestock-water productivity, namely (i) improved feed strategy; this could be done through promoting none grain feed sources with high water productivity, uses of crop residues and by products as feed, and adopt practice that encourage more uniform grazing; (ii) conserving water through managing animals in a way that reduce land and water degradation (e.g. over grazing, erosion and nutrient depletion) including adopting nutrient recycling principles; (iii) enhancing animal productivity through better livestock health, nutrition and animal husbandry practices and; iv) providing adequate quality of drinking water synchronized with available feed. Moreover, additional interventions that would enhance livestock-water productivity include increasing the availability of mineral blocks in pastures and water, improve the digestibility of low quality crop residue and strategic mix of livestock feed.

Furthermore, livestock interventions to reverse degraded lands in smallscale livestock systems include: i) gaining the confidence of community experimenters; ii) minimising soil erosion of grazing and pasture lands through physical and biological measures; iii) increasing soil organic matter through improved forages, improved management of pasture lands, manure and crop residues; iv) improving the water budget of the system through water conservation measures; v) increasing the nutrient status of the soil through improved nutrient recycling and application of key nutrients; and v) adopting integrated approaches enhancing the productivity of the crop-livestock systems, particularly through improved livestock management.

#### *Opportunities for scaling-up Livestock Systems based on Integrated Land and Natural Resource Approaches*

The following interventions, emerged from the research work of national, regional and international research institutions in East Africa, could address the growing concerns of Livestock-environment interaction at farm and higher scales and are envisaged from the perspective of harmonizing livestock to the existing crop livestock systems of SSA. Feed and fodder requirements for livestock presents the crucial interface at which positive and negative of effects of livestock are decided. Feed and fodder obviously drive livestock productivity, and they are commonly the major input factor deciding the economic return from animal husbandry. Ingested feed and fodder carbon and nitrogen inefficiently converted to into meat and milk; contribute substantially to the greenhouse gases (Blummel et al., 2001).

The following approaches to promoting efficient feeding strategies have shown promise for scaling up:

*Legume forage banks:* Starting from the early 80s, the International Institute of Tropical Agriculture (IITA) and the International Livestock Research Centre for Africa (ILCA), the current International Livestock Research Institute (ILRI), promoted alley cropping and forage banks, with multipurpose

legume shrubs as key strategies, to boost livestock production and improve soil fertility through nitrogen fixation and addition of nutrients supplied as green manures or mulch.

*Integrating food-feed crops.* Generally where land and water are allocated and used exclusively for fodder production, the efficiency of conversion of natural resources into livestock product is commonly low (even though absolute livestock production might be high). A range of management options exist for increasing biomass production in mixed crop livestock systems. These include intercropping, thinning-out of densely planted crops, and of course fertilizer application (Blummel et al., 2001). For instance in the dry savannah of west Africa, Tarawali et al (2001) reported that one ha of improved cowpea could benefit a farmer by an extra 50 kg meat per annum from better nourished animals, and also produce over 300 kg more cereal grains as a result of improved soil fertility.

*Increasing livestock feed through growing crop mixtures:* crop mixtures reduce risk in drought prone areas (such as much of SSA). For example, where forage legumes are relay cropped with another crop, the legume may still yield a useful harvest once the drought affected crop or the early maturing component, is harvested. The relay cropped forage can produce up to 4 tonnes of dry matter ha<sup>-1</sup> of high quality fodder using the residual moisture and nutrients, without competing with the main food or cash crop and thus not interfering with the production objectives of farmers (Amede et al. under preparation). This suggests increased water productivity at farm and higher scales.

*Forage legumes in degraded farms and systems (decision guides):* Producers using crop-livestock systems need reliable and accurate information on where to grow forages, the costs and benefits (both long- and short-term) of introducing forage legumes into their systems, and how to identify the spatial and temporal niches for integration of forages with win-win benefits of soil fertility restoration, erosion control, increasing vegetative cover and minimizing land degradation. Decision guides which could guide farmers and development actors to target legume interventions, which have been tested across communities and systems, are currently available.

*Soil and water conservation as niches for integration of forages:* Protecting upper watersheds is key not only to enable the sustainable flow of water to downstream users but also to minimize land degradation and erosion of soils and biodiversity. Besides minimizing erosion and run-off, these interventions became important niches for integration of livestock feed in various systems. The multiple use of forages as biological stabilizers and sources of high quality feed, particularly for calves and milking cows during the dry season, is a very important incentive for integration and promotion of forages.

*Zai systems as forage niches.* Livestock-water and -nutrient productivity could be enhanced through adoption of water and nutrient saving technologies, particularly in degraded farms and landscape niches. Zai is a water and nutrient harvesting intervention, developed by farmers in the Burkina Faso in response to the recurrent drought of the 1970s and 1980s. When farmers planted forages (e.g. Vetch, Napier grass) treated by Zai pits, forage yield was as much as 10 fold while tuber yields of potato was about 5 fold compared to untreated plots (Amede, under preparation), the benefits being the highest in degraded farms and systems.

*Increasing livestock feed through spot application of fertilizers:* In dry land, mixed crop-livestock systems of SSA, crop and livestock productivity is constrained not only by shortage of water but also nutrient deficiency. At Sadore where the annual average rainfall is 560mm, the non use of fertilizers resulted

in a harvest of 1.24 kg of pearl millet grain per mm of water while the use of fertilizers resulted in the harvest of 4.14 kg of millet grain per mm of water (ICRISAT, 1985).

*Improved manure management:* Manure is a key resource to reverse land degradation and improve soil water holding capacity, thereby enhancing water productivity. There are several practical interventions that producers can adopt to improved the quality of the manure generated by livestock. Runoff can be prevented from passing across the feedlot surface by installing up gradient ditches to reduce significantly the volume of wastewater; storage lagoons and holding ponds can be used to contain excess wastewater; manure can be stockpiled at a safe distance away from any water supply, and grass filter strips, filter fencing, or straw bales can filter solids and nutrients in runoff. Composting manure will help to reduce volume and to enhance the value and acceptance of manure as a source of plant nutrients. The efficiency of manure is also improved when manure use is combined with water conservation technologies, like 'Zai' pits.

*Outfield grazing management on water and nutrient resources:* Free grazing systems, which is common in pastoral and mixed crop livestock systems of SSA and South Asia, is considered as a major cause of land degradation and depletion of water resources. Experiences of the African Highlands initiative indicates that the following approaches can significantly improved sustainability of outfield grazing: (i) introducing fast growing forages as forage banks, particularly in homestead areas, improved crop residue management, introducing rotational pasture management (ii) assisting communities to identify spatial and temporal niches for forages and to access technologies to increase feed production and livestock productivity; (iii) assisting communities in developing local rules and byelaws to guide the management of free grazing.

#### *Recommendations for practitioners and/or policy makers*

In general, policy makers have not considered the effect of livestock on land productivity as a policy objective in itself, but as an input into achieving other policy objectives. Land degradation is not seen as posing a serious policy concern unless it threatens livelihood and immediate regional and national objectives (Scherr, 1999). The ongoing challenge is therefore to identify policies, institutions, and technologies which will enhance the positive and mitigate the negative impacts of livestock on the environment. ILRI has identified resource management policy research as a key strategy (Euhi et al. 2003), which includes establishing trends on how current livestock management affects resource use and conservation in the future, and how changes in government policies affecting those institutions and in terms sharing risks, credit, commodity pricing and selected macroeconomic policies on resource use and the environment. The most relevant policy area related to sustainable land management is the policy framework that should promote the mitigation of negative effects of livestock production on environmental health, including the following:

1. Integrating livestock in designing irrigation and other water related development projects. As the current policy of SSA countries is biased towards crop production, livestock drinking and feed is not part of the design of irrigation projects. Integrating livestock to the wider water development agenda will boost livestock-water productivity and promote sustainable land management.
2. Policies which promote integrated crop-livestock systems, whereby crop and livestock enterprises are complementing to each other, resource recycling is practiced, water depletion and nutrient mining is minimized and key critical external inputs are introduced.

3. Participatory policy formulation to regulate stocking rate in pastoral systems together with allocation of land to groups will enhance resource use efficiency.
4. Promote well managed kraaling, based around keeping livestock on selected areas over a give period of time to provide fertilizer for crops while reducing nutrient losses from manures through volatilization and runoff
5. Employing full cost recovery for developing water points and animal health services will encourage livestock keepers to adjust stocking rates to the carrying capacity of the system.

Promoting access to water points and feed resources across scales, particularly for the poor, will be an incentive to promote gender equity and improve land and water management practices as poor farmers may be willing to invest labor and other resources to guarantee the sustainable productivity of their limited number of livestock.

#### *Investment Needs*

- Promoting small-scale irrigation through diversions, water harvesting, and ground water use, with due consideration to environmental consequences and upstream-downstream relationships, could be an important policy strategy to improve livestock-environment interaction. Increased access to irrigation will increase feed availability from crop fields, forages, grasslands, and other niches that will reduce the grazing pressure on marginal lands.
- Incentives for strategically located markets and value-added processing to facilitate livestock sales and thus match livestock resource (i.e., feed, water), demands pressure on carrying capacity of the natural resource base.

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## **Web Resources**

<http://www.iwmi.cgiar.org/assessment/>

## **Endnote**

1. A TLU is equivalent to 250 kg live weight.

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## **Investment Note: Integrated Nutrient Management in the Semi-Arid Tropics**

### *Summary*

Increasing needs of food, feed, and fiber for the ever-increasing population in the semi-arid tropical (SAT) regions of the developing world is putting pressure on the rainfed areas to make greater contribution from the vast area under dryland agriculture. The smallholder farmers rely on the dryland subsistence productivity for their livelihood and the productivity of dryland systems remains low because of low and erratic distribution of rainfall coupled with low to negligible inputs of nutrients. Maintenance of soil organic matter is a challenge, because of competing uses of organic and crop residues. Organic matter is not just the source of nutrients, it is essential for preserving soil's physical, chemical, and biological integrity for the soil to perform its productivity and environment-related functions on a continuing basis. With little investment in the management of soils, large areas under dryland agriculture are in various stages of physical, chemical, and biological degradation. To achieve sustainable improvement in dryland productivity, strategies are highlighted that facilitate an integrated land and water management and conservation approach along with a special focus on integrated (soil) nutrient management (INM).

### *Key Sustainable Land Management Issues*

Farm holdings in the SAT are not only distinct in terms of size, shape, and location on a toposequence but vary widely for the cropping patterns, and quality and quantity of nutrients used for crop production. A major constraint is the timely availability of knowledge and right information about soil health for the farmers (Singh et al. 2004). As described below, farmers do not know what is ailing their farm in general. It is of utmost importance to establish quality soil analytical laboratories in each district of a state to provide timely and correct information to the farmers relating to the diagnosis of soil fertility constraints (Wani et al. 2003, 2005).

Apart from water shortage, the productivity in rainfed systems is also constrained by low soil fertility. The soils in the SAT regions generally have low organic matter and nutrient reserves. Soil erosion removes the top soil layer, which not only results in the loss of soil but in loss of organic matter and plant nutrients, which largely are stored in the top soil layer (Wani et al. 2003). Among the major nutrients, nitrogen is universally deficient and phosphorus deficiency ranks only next to nitrogen in most of the SAT soils. Our work has shown that potassium reserves in the SAT soils are generally adequate (Rego et al. 2007). Most of the SAT soils have low to moderate phosphorus sorption capacity, and most of the rainfed systems require low to moderate rates of phosphorus applications to meet their phosphorus requirements also considering residual benefits (Sahrawat et al. 1995; Sahrawat 1999, 2000). Many of the farmers' fields in the SAT regions of India are deficient in secondary and micronutrients. Our extensive survey of the farmers' fields in the SAT regions of India revealed that the deficiencies of sulfur, boron, and zinc are very widespread and in most cases 80-100 percent farmers' fields were found critically deficient in these nutrients (table 3.7) (Rego et al. 2007).



**Table 3.7 Chemical Characteristics of 924 Soil Samples Collected from Farmers' Fields in Three Districts of Andhra Pradesh, India, 2002-2004**

District	No. of Fields		pH	Organic C g kg <sup>-1</sup>	Total N -----mg kg <sup>-1</sup> ----- ---	Olsen-P mg kg <sup>-1</sup>	Exc h. K	Extractable nutrient elements (mg kg <sup>-1</sup> ) S                      B                      Zn		
Nalgonda	256	Range	5.7 - 9.2	1.2 - 13.6	144 - 947	0.7 - 37.6	34 - 784	1.4 - 93.0	0.02 - 1.48	0.08 - 16.00
		Mean	7.7	4.0	410	8.5	135	7.00	0.26	0.73
		% deficient <sup>a</sup>						86	93	73
Mahabubnagar	359	Range	5.5 - 9.1	0.8 - 12.0	123 - 783	0.7 - 61.0	25 - 487	1.1 - 44.0	0.02 - 1.62	0.12 - 35.60
		Mean	7.1	3.6	342	9.1	117	11.5	0.22	1.34
		% deficient						73	94	62
Kurnool	309	Range	5.6 - 9.7	0.9 - 10.6	26 - 966	0.4 - 36.4	33 - 508	1.3 - 68.2	0.04 - 1.64	0.08 - 4.92
		Mean	7.8	3.4	295	7.9	142	5.6	0.34	0.42
		% deficient						88	83	94

<sup>a</sup> Represents the critical limits in the soil used : 8-10 mg kg<sup>-1</sup> for calcium chloride extractable S; 0.58 mg kg<sup>-1</sup> for hot water extractable B; 0.75 mg kg<sup>-1</sup> for DTPA extractable Zn.

Source: Authors

### Lessons Learned

Several microorganisms in the soil decompose plant and animal residues and several groups of microorganisms are involved in important biological processes. Microorganisms regulate nutrient flow in the soil by assimilating nutrients and producing soil biomass (immobilization) and converting carbon, nitrogen, phosphorus, and sulphur to mineral forms (mineralization). Important findings include:

- Symbiotic nitrogen fixers–symbiotic partnership between bacteria (*Rhizobium/Bradyrhizobium*) and legumes contributes substantially (up to 450 kg N/ha/yr) to total BNF.
- Non-symbiotic and associative nitrogen fixers-inoculation with bacteria (*Azotobacter* and *Azospirillum*) reduces N requirement of cereals or non-legume crops up to 20 kg/ha.
- Plant growth promoting rhizobacteria (PGPR) – these improve plant growth through hormonal effects and reduce disease severity.
- Phosphate solubilizing microorganisms – these bacteria and fungi solubilize inorganic phosphates and make them available to plants in usable form.
- Vesicular-arbuscular mycorrhizae (VAM) -- these help increased uptake of nutrients such as P, S, Cu, and improve plant growth.

## **Biological Nitrogen Fixation (BNF)**

- BNF is an economically attractive and ecologically-sound process and is an integral part of nitrogen cycling in nature
- *Rhizobium* inoculation is practiced to ensure adequate nodulation and BNF.
- Efficient strains of *Rhizobium* /*Bradyrhizobium* supplied as inoculants are used as biofertilizers by seed or soil inoculation.

Recent results from a long-term study conducted under rainfed conditions on a Vertisol for 12 years, demonstrated that the inclusion of grain legumes such as pigeonpea and chickpea in the production systems not only provided extra income, but increased the productivity of succeeding or intercropped cereal such as sorghum and maize. Such systems also maintained the soil N status (Rego and Rao 2000). Nitrogen mineralization potential of soil under legume-based systems was two-fold higher than only cereal-cereal system (Wani et al. 1995). Another long-term study showed that cropping systems involving legumes, land and water management factors, such as the broad-bed and furrow landform and use of inorganic fertilizers, increased the organic matter, available nitrogen and phosphorus status of soils along with improved soil physical and biological properties (table 3.8). Results also showed that in the improved system higher carbon was sequestered and the biological properties of the soil were improved, which led to higher systems' productivity and carrying capacity of land (both of men and of animals). The application of P to the improved system increased the amount of carbon sequestered by 7.4 t carbon/ha in 24 years (Wani et al. 2003).

### *Opportunities for Sustainable Land Management: Products and Services*

To enhance and sustain SAT agricultural productivity and food security there is a need to adopt (INM) strategy. The INM strategy includes maintenance or adjustment of soil fertility and plant nutrient supply to sustain the desired level of crop productivity using all available sources of nutrients (e.g., soil organic matter, soil reserves, biological nitrogen fixation (BNF), organic manures, mineral fertilizers, and nutrients) supplied via precipitation and irrigation water. INM is a holistic system approach focusing on the cropping system rather than on individual crop. INM focuses on the farming system rather than on individual field. It does not preclude the use of renewable nutrient sources such as BNF and organic manures and minimal use of mineral fertilizers.

Organic matter is not just the reservoir of plant nutrients. Organic matter favorably influences physical and biological properties, and productivity of soils. High prevailing temperatures in the tropics coupled with low net primary productivity in the dry regions, results in low organic matter reserves in the SAT soils.

**Table 3.8 Biological and Chemical Properties of Semi-arid Tropical Vertisols in 1998 After 24 Years of Cropping Under Improved and Traditional Systems in Catchments at ICRISAT Center, Patancheru, India.**

Properties	System	Soil depth (cm)		SE± *
		0-60	60-120	
Soil respiration (kg C ha <sup>-1</sup> )	Improved	723	342	7.8
	Traditional	260	98	
Microbial biomass C (kg C/ha)	Improved	2676	2137	48.0
	Traditional	1462	1088	
Organic carbon (t C/ha)	Improved	27.4	19.4	0.89
	Traditional	21.4	18.1	
Mineral N (kg N/ha)	Improved	28.2	10.3	2.88
	Traditional	15.4	26.0	
Net N mineralization (kg N/ha)	Improved	-3.3	-6.3	4.22
	Traditional	32.6	15.4	
Microbial biomass N (kg N/ha)	Improved	86.4	39.2	2.3
	Traditional	42.1	25.8	
Non-microbial organic N (kg N/ha)	Improved	2569	1879	156.9
	Traditional	2218	1832	
Total N (kg N/ha)	Improved	2684	1928	156.6
	Traditional	2276	1884	
Olsen P (kg P/ha)	Improved	6.1	1.6	0.36
	Traditional	1.5	1.0	

\* SE=Standard error of mean.

Source: ICRISAT

Organic manures are of two types: (a) bulky-FYM, composts (rural and town), crop residues; and (b) concentrated-oilcakes, poultry manure, slaughter house waster, etc. FYM is the most commonly used organic manure particularly for high-value crops. It is prepared from animal-shed wastes and crop residues including stover and contains 0.5-1.0 percentN, 0.05-0.07 percent P and 0.03-0.35 percent K. Crops residues can be recycled by composting, vermicompositing, mulching, and direct incorporation. Based on N content, organic manures are less efficient than mineral fertilizers; however combined use of these nutrient sources is superior to using mineral fertilizer or organic manure alone. A combination of crop residue restitution (based on the availability), fallowing or green manuring can be used to maintain organic matter levels in the soil.

In farms as well as in homes large quantities of organic wastes are generated regularly. Besides agricultural wastes, large quantities of domestic wastes are generated in cities and rural areas that are wasted by burning or used as land fills. These valuable nutrients in residues can be effectively used for increasing the agricultural productivity using earthworms to convert the residues into valuable source of plant nutrients (table 3.9). The process of preparing valuable manure from all kinds of organic residues with the help of earthworms is called “vermicomposting” and this manure is called “vermicompost.”

Vermicompost can be prepared from all types of organic residues such as agricultural residues, sericultural residues, animal manures, dairy and poultry wastes food industry wastes, municipal solid wastes, biogas-sludge, and bagasse from sugarcane factories.

Vermicompost can be prepared by different methods in shaded areas such as: (a) on the floor in a heap; (b) in pits (up to 1 m depth); (c) in an enclosure with a wall (1 m height) constructed with soil and rocks or brick material or cement; and (d) in cement rings. The procedure for preparation of vermicompost is similar for all the methods (figure 3.15).

**Figure 3.15 Farm Women Learning (Vermicompost Preparation).**



Source: ICRISAT

Vermicompost can be used agricultural, horticultural, ornamental, and vegetable crops at any stage of the crop. Vermicompost is a rich source of major and micro plant nutrients (See table 3.9), and can be applied in varying doses in the field. << insert Table 3.9 here >>

**Table 3.9 Nutrient Composition of Vermicompost**

<b>Nutrient element</b>	<b>Vermicompost (%)</b>
Organic carbon	9.8–13.4
Nitrogen	0.51–1.61
Phosphorus	0.19–1.02
Potassium	0.15–0.73
Calcium	1.18–7.61
Magnesium	0.093–0.568
Sodium	0.058–0.158
Zinc	0.0042–0.110
Copper	0.0026–0.0048
Iron	0.2050–1.3313
Manganese	0.0105–0.2038

Source: ICRISAT

#### *Rational for Investment*

On-farm studies made on smallholder farms for three seasons in the SAT region of Zimbabwe showed that the applications of fertilizer N (8.5 kg N/ha) in combination with manure application at 3 or 6 t/ha has the potential to improve the livelihoods of farmers through the use of small rates of manure in conjunction with fertilizer N under semi-arid conditions. The maize yields of the crop were drastically increased by the applications of manure and N at small rates (Ncube et al. 2007).

Our recent on-farm research in the SAT regions of India showed that balanced nutrition of rainfed crops is crucial for sustainable increase in productivity and maintenance of fertility. For example, in the SAT regions of India where most of the farmers' fields were found deficient not only in nitrogen, phosphorus, but also in sulfur, boron and zinc, the application of sulfur, boron and zinc

with nitrogen and phosphorus significantly increased the yield (30-120 percent) of field crops including sorghum, maize, castor, sunflower and groundnut (Rego et al. 2007).

#### *Recommendations for Practitioners*

The rainfed production systems have two major constraints in the form of water shortages and general low soil fertility. To make these systems sustainable at reasonable productivity levels, there is need to integrate soil and water conserving practices with balanced nutrition of crops by adopting INM. The knowledge available about different sources of nutrients such as BNF, organic manures, and mineral fertilizers can be used to develop a suitable strategy for INM to sustain crop productivity. INM strategy is realistic, attractive, and environment-friendly. INM will enhance the efficiency of biological, organic, and mineral inputs for sustaining productivity of SAT soils. Judicious and balanced use of nutrients through biological sources, mineral fertilizers, and organic matter is a prerequisite to make the rainfed agriculture efficient through increased rainfall use efficiency. Specific recommendations include:

- Different crops require different rhizobia.
- Select the right type of biofertilizer (inoculant).
- The inoculant must be fresh and within the expiration date limit.
- Use well-tested inoculants produced by reputable manufacturers.
- Users in India must insist on quality inoculants with ISI mark.
- Prepare inoculum slurry using a sticking agent such as jaggery, rice porridge, or gum Arabic.
- Mix seeds with inoculum slurry by hand.
- Dry seeds on a plastic sheet kept under a shade.
- Sow seeds within 48 hours after inoculation.
- Use high nitrogen-fixing crops/varieties.
- Practice mixed and intercropping (i.e., row and strip) with legumes.
- Use appropriate tillage practices, landform treatments and nutrient amendments.

Use appropriate mineral fertilizers in amounts to meet the nutrients requirements. Ensure that efficiency of applied fertilizers is optimized through adoption of suitable practices.

- Form or type – as recommended for the crop.
- Method – furrow placement and covering with soil instead of broadcasting.
- Time - split N doses instead of one application
- Quantity - just sufficient to meet plant demand without adversely affecting biological nitrogen fixation
- Undertake detailed soil analysis to identify soil fertility constraints limiting crop production.
- Develop suitable nutrient management recommendations from soil analysis results and share knowledge with the farmers and stress the need for adopting INM strategy to maintain fertility and productivity.

- Optimize and harness full potential of available biological and organic sources and use chemical fertilizers to supplement the gap in the nutrient requirements of the production system.
- Adopt an integrated rather than a piece-meal approach for sustainable development. For example, for most land management issues, it will also be necessary to address water management, fertility management, pest management, and improved cultivars, as all these components are synergistically inter-linked with sustainable land management.

*Investment Needs by Local and National Governments or Other Donors*

- Investments are urgently needed in establishing high-quality, reliable and functional soil-plant analytical laboratories in the developing countries. The cost to provide analytical support for the analysis of soil and plant samples could range \$20,000 to \$100,000 depending on the extent of automation and the number of samples to be analyzed in an year.
- Enhancing awareness among the farmers, development agents, and policy makers to discuss soil quality and adopt sustainable INM practices. For minimizing land degradation, continued investments in capacity building and training of personnel involved are needed.
- Investments to enhance the use of biological and organic resources through incentives for increased adoption are needed for sustainable land management.

*Policy and Financial Incentives*

- Enabling policies and incentive mechanisms for greater adoption of INM practices.
- Timely availability of quality products and knowledge on quality products and sustainable INM practices to the farmers, by establishing appropriate institutions.
- Enabling policies and mechanisms to produce, distribute, and use various sources of different plant nutrients.

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## **Investment Note: Integrated Natural Resource Management for Enhanced Watershed Function and Improved Livelihoods in the Semi-Arid Tropics**

### *Summary*

The community watershed model has become popular since it brings together, as a package for rural development, the best of expertise available locally and from all the consortium partners. While using the micro watershed as a geographical unit for soil and water conservation and management, the impact is strengthened with improved agronomical practices and diversified income generation activities. Water management is used as an entry point for enhancing agricultural productivity and rural incomes. The consortium's approach aims to showcase increased incomes for villagers. Once the villagers are convinced that the innovations improve their livelihood security, they become ambassadors to the cause, convincing neighboring villages to practice community watershed development technologies.

The success of the Kothapally example has led to the acceptance of the watershed approach in large areas of India, as well as China, Thailand and Vietnam. Countries and agencies in SubSaharan Africa are also becoming involved.

The data show that, using community watershed approach, productivity and incomes can be doubled through collective action and knowledge-based management of natural resources. Water management is just an entry point and not an end in itself. Community watershed development needs to go further and adopt the livelihood approach with technical backstopping from multi-disciplinary teams from different institutions working together in a consortium to harness the benefits of holistic IGNRM approach through empowerment of stakeholders.

### *Introduction*

In rainfed tropical areas of Asia and Africa, natural resources are severely degraded due to soil erosion, nutrient mining, depleted groundwater levels, waterlogging, and removal of vegetative cover. Although in the past, drylands have sustained large populations, many dryland areas are increasingly showing up as hotspots of poverty and malnutrition. In addition, many such areas are predicted to face more frequent and severe droughts due to increasing climate variability and eventual change (Wani et al 2002). Monsoon rains are erratic and few torrential down pours (e.g, Adarsha Watershed, Kothapally in Andhra Pradesh, India on 24<sup>th</sup> August 2000 received 345 mm of rainfall in 24 h which is about 40 percent of mean annual rainfall) cause severe runoff, which removes nutrient and carbon-rich top soil thereby contributing to land degradation.

The community watershed approach is being used to overcome the livelihood constraints posed by natural resource degradation by way of the Integrated Genetic and Natural Resource Management (IGNRM) approach. In this approach, research and development activities are implemented at landscape scales with benchmark sites representing the different Semi-Arid Tropics (SAT) agro-ecoregions. The entire process revolves around the principles of empowerment, equity, efficiency, and environment, which are addressed by adopting specific strategies prescribed by consortium institutions from the scientific, non-government, government, and farmers groups. This approach addressed the issues of participation, equity, sustainability, and technical support, which were found



to be important constraints for enhancing the impact of watershed programs in India based on a meta-analysis of 311 case studies (Joshi et al. 2005).

### *Presentation of innovation*

The community watershed model has become popular since it brings together as a package for rural development the best of expertise available locally and all the consortium partners. While using the micro watershed as a geographical unit for soil and water conservation and management, the impact is strengthened with improved agronomical practices and diversified income generation activities. Water management is used as an entry point for enhancing agricultural productivity and rural incomes. Knowledge-based entry point to build rapport with the community in place of money/capital-based entry point enhanced community participation through tangible economic benefits to individuals through enhanced productivity. Farmers' participatory research and development (PR&D) approach is fully operationalized and no free inputs are provided to the farmers. The consortium's approach aims to showcase increased incomes for villagers. Once they are convinced that the innovations improve their livelihood security, they become ambassadors to the cause, convincing neighboring villages to practice community watershed development technologies (Wani et al. 2006).

While the activities initiated by ICRISAT and partners started with soil and water conservation, the watersheds became the site for implementing IGNRM. In Adarsha Watershed, Kothapally in Andhra Pradesh, India, the package of interventions included introducing broad-bed and furrow cultivation, planting *Gliricidia* on the bunds for green manure, introducing new crops, high-yielding and stress tolerant improved cultivars and cropping systems, innovating with pest management techniques and developing micro-enterprises for additional income generation along with low-cost rainwater harvesting and groundwater recharging structures throughout the toposequence.

Choosing appropriate cropping sequence and matching crop rotation with the soil profile and changing rainfall patterns helped minimize the impact of drought in Kothapally. A combination of maize-pigeonpea and maize followed by chickpea proved to be most beneficial as these crops could utilize the soil moisture more efficiently and farmers shifted from cotton-based system. Moreover, studies showed that soils in Andhra Pradesh, Karnataka, Madhya Pradesh, Tamil Nadu, Gujarat and Rajasthan were not only thirsty but hungry too and suffered from critical deficiency of micronutrients such as zinc, boron and sulphur along with nitrogen and phosphorus. Adding these micronutrients to the soil resulted in 28 to 70 percent increase in the yields of crops and balanced fertilizer application with N and P along with micronutrients increased yields upto 120 percent (Rego et al. 2007).

In Tad Fa and Wang Chai watersheds in Thailand, and Thanh Ha and Huong Dao watersheds in Vietnam, the package of practices included introduction of improved crop varieties, construction and rehabilitation of farm ponds, introduction of legumes in the cropping systems, vegetative contour bounds, slaggered trenching, planting *Gliricidia* on bunds, growing fruit trees on steep slopes, contour cultivation on mild slopes, vegetative bunds with vetiver plantation, introduction of innovative integrated pest management (IPM) techniques such as using molasses to trap moths and diversifying cultivation with horticultural crops.

In China, farmers from Lucheba and Xioaoxincum watersheds have harvested rainwater in underground cisterns and surface tanks, diversified the systems growing high-value vegetables and fruits along with innovative IPM options such as using light traps and tobacco waste, and earned

additional income from allied activities such as rearing of pigs, rabbits and biogas production. Leujiagh village in Lucheba watershed has become a model biogas village for the country using plant and animal wastes (pig manure) for biogas production, meeting the needs of sanitation and energy self-sufficiency.

#### *Benefits and impact of activity*

Many innovations are being implemented with success in the watersheds. In Thailand, an innovative IPM technique mixing molasses with water and storing in open bottles to trap adult moths before they lay their eggs has practically eliminated the use of chemical pesticides in vegetable crops.

The innovative activities also give income-generating activities to women's self-help groups (SHG) and landless farmers. In Kothapally and hundreds of watershed in Andhra Pradesh, Karnatka, Madhya Pradesh, Gujarat and Rajasthan, the members of the SHG feed parthenium weed to earthworms, generate valuable vermicompost, and earn about Rs 500 per person per month from its sale. The SHG also produced and sold biopesticide made from neem and *Gliricidia* plant leaves using earthworms. Catering to the needs of generating biodiesel plantations, the SHG members started a nursery to raise seedlings of *Jatropha* and *Pongamia*.

Likewise, the women's SHG in Goverdhanpura in Bundi district of Rajasthan, India has taken to manufacturing washing powder as an income-generating activity. The small profit helps run the SHG and give an income to women members.

*Increasing crop productivity* is common in all the watersheds and is evident soon after the inception of watershed interventions. To cite few cases, in benchmark watersheds of Andhra Pradesh, improved crop management technologies increased maize yield by 2.5 times and sorghum by 3 times (Table 3.10). Over-all, in 65 community watersheds (each measuring approximately 500 ha), implementing best-bet practices resulted in significant yield advantages in sorghum (35–270 percent), maize (30–174 percent), pearl millet (72–242 percent), groundnut (28–179 percent), sole pigeonpea (97–204 percent) and as an intercrop (40–110 percent). In Thanh Ha watershed of Vietnam, yields of soybean, groundnut and mungbean increased by three to four folds (2.8–3.5 t ha<sup>-1</sup>) as compared with baseline yields (0.5 to 1.0 t ha<sup>-1</sup>) reducing the yield gaps between potential and farmers' yields. A reduction in N fertilizer (90–120 kg urea ha<sup>-1</sup>) by 38 percent increased maize yield by 18 percent. In Tad Fa watershed of northeastern Thailand, maize yield increased by 27–34 percent with improved crop management.

*Improving water availability* in the watersheds was attributed to efficient management of rainwater and *in-situ* conservation, establishing low cost, water harvesting structures (WHS) throughout the toposequence improved groundwater levels benefiting many small farmers. Even after the rainy season, the water level in wells nearer to WHS sustained good groundwater yield. In the various watersheds of India like Lalatora, in M.P, treated area registered a groundwater level rise by 7.3 m. At Bundi, Rajasthan, the average rise was at 5.7 m and the irrigated area increased from 207 ha to 343 ha. In Kothapally watershed, the groundwater level rise was at 4.2 m in open wells (Figure 3.16). The various WHS resulted in an additional groundwater recharge per year of approximately 428,000 m<sup>3</sup> on the average. With this improvement in groundwater availability, the supply of clean drinking water was guaranteed. In Lucheba watershed in southern China, a drinking water project, which constitutes a water storage tank and pipelines to farm households, was a joint effort of the community and the watershed project. This solved the drinking water problem for 62 households and more than 300 livestock. This was the main motivation for the excellent farmers' participation in

the project. On the other hand, collective pumping of well water and the establishment of efficient water distribution systems, enabled farmers group to earn more income by growing watermelon provided maximum income for households in Thanh Ha watershed in Vietnam.

**Table 3.10 Seasonal rainfall, runoff and soil loss from different benchmark watersheds in India and Thailand**

Watershed	Seasonal rainfall (mm)	Runoff (mm)		Soil loss (t ha <sup>-1</sup> )	
		Treated	Untreated	Treated	Untreated
Tad Fa, Khon Kaen, NE Thailand	1284	169	364	4.21	31.2
Kothapally, Andhra Pradesh, India	743	44	67	0.82	1.90
Ringnodia, Madhya Pradesh, India	764	21	66	0.75	2.2
Lalatora, Madhya Pradesh, India	1046	70	273	0.63	3.2

**Figure 3.16. Types of rainwater harvesting (stone and earthen check dams), storage (tanks) and groundwater recharging (wells) structures.**

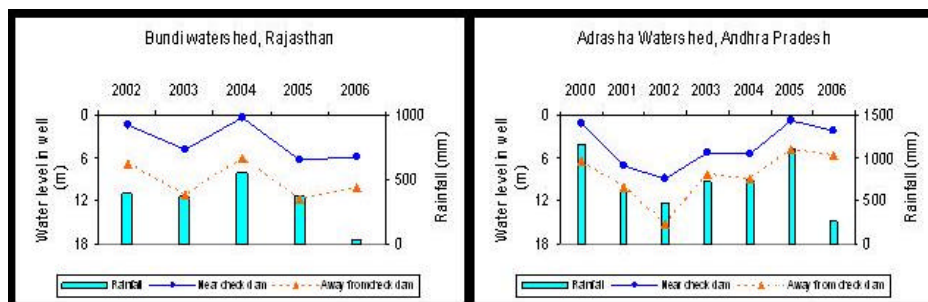


Through improved yields and income-generating opportunities, the families in the watershed projects have more money in their hands. For instance, in Kothapally, the average income (including livestock and non-farming sources) was Rs 42,500 (US\$ 1036.6) in 2001. In comparison, the average income in the neighboring villages without watershed management approaches was Rs 27,600 (US\$ 673.1). Even in the drought year of 2002, Kothapally farmers earned more from crop cultivation compared to the farmers in the neighboring villages, enabling reduced migration from Kothapally village. In the Tad Fa and Wang Chai watersheds in Thailand, there was a 45 percent increase in farm income. On the whole, the farmers earned an average net income of 45,530 baht (US\$1230) per cropping season (Shiferaw et al. 2006).

Improved land and water management practices along with integrated nutrient management (INM) comprising of applications of inorganic fertilizers and organic amendments such as crop residues, vermicompost, farm manures, *Gliricidia* loppings as well as crop diversification with legumes not only enhanced productivity but also improved soil quality. Increased carbon sequestration of 7.4 t

ha<sup>-1</sup> in 24 years was observed with improved management options in a long-term watershed experiment at ICRISAT. Normalized difference vegetation index (NDVI) estimation from the satellite images showed that within four years, vegetation cover increased by 35 percent in Kothapally. The IGCRM options in the watersheds reduced loss of NO<sub>3</sub>-N in run off water (8 vs 14 kg N ha<sup>-1</sup>). Introduction of IPM in cotton and pigeonpea substantially reduced the number of chemical insecticidal sprays during the season and use of pesticides reduced the pollution of water bodies with harmful chemicals.

**Figure 3.17. The impact of watershed interventions on groundwater levels at two benchmark sites in India.**



*Conserving biodiversity* in the watersheds was engendered through participatory NRM. The index of surface percentage of crops (ISPC), crop agro-biodiversity factor (CAF), and surface variability of main crops changed as a result of integrated watershed anagement (IWM) interventions. Pronounced agro-biodiversity impacts were observed in Kothapally watershed where farmers now grow 22 crops in a season with a remarkable shift in cropping pattern from cotton (200 ha in 1998 to 100 ha in 2002) to a maize/pigeonpea intercrop system (40 ha to 180 ha); thereby changing the CAF from 0.41 in 1998 to 0.73 in 2002. In Thanh Ha, Vietnam the CAF changed from 0.25 in 1998 to 0.6 in 2002 with the introduction of legumes. Similarly, rehabilitation of the common property resource land in Bundi watershed through the collective action of the community ensured the availability of fodder for all the households and income of US \$ 1670 y<sup>-1</sup> for the SHG through sale of grass to the surrounding villages. Aboveground diversity of plants (54 plant species belonging to 35 families) as well as below ground diversity of microorganisms (21 bacterial isolates, 31 fungal species and 1.6 times higher biomass C) was evident in rehabilitated CPR as compared to the degraded CPR land (9 plant species, 18 bacterial isolates and 20 fungal isolates of which 75 percent belong to *Aspergillus* genus) (Wani et al. 2005).

*Promoting natural resource management (NRM) at landscape level.* Benefiting from data obtained from using new science tools like remote sensing, a comprehensive understanding of the effects of the changes (i.e. vegetation cover on degraded lands) in the watersheds is made. This in turn has provided the indicators to assess agricultural productivity. Promoting NRM at the landscape level by using tools that provide the needed database is anticipated to have better impact because of the possible integration of all the factors (natural resources with the ancillary information).

While there were some interventions at plot to farm level, the impact factors of NRM such as sustainability of production, soil and water quality, and other environment resources have been looked at from a landscape perspective. Equal attention was focused on both on-site and off-site impacts. The effect of water conservation at the upper ridge on downstream communities was also

considered. This accounts for some successes in addressing concerns on equity issue like benefits for the poorest people such as the landless who were previously unable to take advantage of improved soil/water conditions in activities implemented only at field scales. It is clear that off-site effects of watershed management – upstream-downstream equity - needs to be strengthened for enhanced impact.

*Enhancing partnerships and institutional innovations* through the consortium approach was the major impetus for harnessing watershed's potential to reduce households' poverty. The underlying element of the consortium approach adapted in ICRISAT-led watersheds is engaging a range of actors with the locales as the primary implementing unit. Complex issues were effectively addressed by the joint efforts of ICRISAT and with key partners namely the national agricultural research systems (NARS), non-government organizations (NGOs), government organizations (GOs), agricultural universities and other private interest groups with farm households as the key decision-makers. In SHGs, like village seedbanks, these were established not just to provide timely and quality seeds. These created the venue for receiving technical support and building the capacity of members like women for the management of conservation and livelihood development activities. Incorporating knowledge-based entry point in the approach led to the facilitation of rapport and at the same time enabled the community to take rational decisions for their development. As demonstrated by ICRISAT, the strongest merit of consortium approach is in capacity building where farm households are not only the sole beneficiaries but researchers, development agents and students of various disciplines are also trained, and policymakers from the NARS sensitized on the entire gamut of watershed activities. Private-public partnership has provided the means for increased investments not only for enhancing productivity but also for building institutions as engines for people-led natural resource management.

#### *Lessons Learned and Scaling Up*

The success of the Kothapally example led to the acceptance of the watershed approach by the Government of Andhra Pradesh for scaling up into 150 watersheds through the Andhra Pradesh Rural Livelihoods Program, supported by the Department of International Development of the UK Government. Observing this success, the Government of Karnataka has also adopted productivity enhancement initiatives in pilot watershed sites and scale out through the World Bank-funded Sujala Watershed Project. With the financial support from the Sir Dorabji Tata Trust, the ICRISAT-led consortium of partners has implemented watershed projects in Madhya Pradesh and Rajasthan in India. Watershed projects are also being implemented in Rajasthan and Tamil Nadu states in partnership with the Confederation of Indian Industry and the Coca Cola Foundation. With funding from the Asian Development Bank, ICRISAT's model of watershed development was implemented in selected villages in India, China, Thailand and Vietnam.

The outcomes of the ICRISAT's watershed research and development activities are also being used for the South-South cooperation among countries in Asia and Africa. Considering the usual long timelag between NRM research and subsequent impact, ICRISAT and the Soil and Water Research Management Network (SWMnet) is focusing on adapting existing knowledge for local conditions, rather than initiating new research. For example, following visits to India by African officials, an MOU between the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the Indian Council for Agricultural Research (ICAR) to facilitate long-term collaboration is in operation. The government of Rwanda, through its agricultural research institute

(ISAR), is working with ICAR to implement pilot sites for the adaptation and demonstration of Indian experiences in integrated management of watersheds.

#### *Recommendations for Practitioners*

- Manage natural resources at smaller catchment scale (500-3000 ha) by adopting sustainable livelihoods approach.
- Adopt holistic community watershed approach using water management as an entry point for improving livelihoods.
- Soil and water conservation measures are just beginning for watershed development and not an end as generally adopted.
- Knowledge-based entry point activity (EPA) promotes better community participation than subsidy-based EPA.
- Adopt productivity enhancement and income-generating activities to ensure tangible economic benefits to individuals for increased collective action in the watersheds.

#### *Investments needs*

- Soil and water conservation measures address long-term sustainability issues and benefits are on-site and off-site. This approach calls for investments by governments/development donors and others.
- Based on topography, socio-economic parameters and infrastructure availability development costs would vary between 500-1500 US \$ per ha.

#### *Policy and financial incentives*

- The success of community watersheds depends on participation and collective action by the members. Policies enabling collective action for management of natural resources are needed.
- More investment in upland/upstream areas are needed to minimize land degradation and to address equity and gender parity issues.
- Artificial divide between rainfed and irrigated agriculture need to be discarded and need to work in a continuum from rainfed to supplemental to fully irrigated systems for making investments to improve livelihoods.
- Financial incentives for poor up-stream people who provide environmental services to downstream people need to be provided to encourage them to be better managers of natural resources.

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## **Investment Note: Enhancing Mobility of Pastoral Systems in Arid and Semi-arid Regions of Sub-Saharan Africa to Combat Desertification**

### *Summary*

Pastoral systems in arid and semi-arid regions of Sub Saharan Africa are well suited to cope effectively, and in an environmentally sustainable manner, with the prevailing harsh and erratic ecological conditions of those regions. The ability of pastoralists to move their herds over large distances and to take refuge in more favorable sites during droughts was critical to their livestock and livelihoods. Moreover, by maintaining the supply of animal food products during regional droughts, they also mitigated the impact of simultaneous crop failures on food security in adjacent more humid areas. Today, however, unfortunately, mobility of pastoralists is increasingly being constrained which is causing the effectiveness of the pastoral system to deteriorate fast. Furthermore, development policies have undermined the basic foundations of pastoralism.

For many years the multiple values and needs of traditional mobile pastoralism have been neglected and/or misunderstood. It is only from the mid seventies that field studies on pastoral systems emerged to help understand seasonal livestock movements, herd-sex structures and productivity, rangelands ecology and the multiple functions of pastoralism. The advantages of opportune and flexible use of natural resources, rather than controlling stocking rates, have only been recently accepted as the recommended scientific basis of livestock development.

Mobile pastoralism can be an efficient and sustainable system. Improving natural rangelands in arid and semi-arid regions would also improve the worlds' carbon storage capacity, biodiversity, and water quality. Arid and semi-arid lands represent about two-third of Africa's total land area of nearly 30 million square kilometers, hosting about 189 million people. Enhancing the condition and availability of natural rangelands and water resources for pastoral production would simultaneously improve wild food availability, provide critical micro-nutrients, and diversify regional rural economies. Moreover, increasing the area and condition of rangelands adjacent to cropping areas, would favor the sustainability and productivity of the cropping systems through reduced soil erosion because of increased water retention capacity of the rangelands and through increased availability of animal manure per cropping area unit. Finally, mixed crop-rangeland systems would reduce the impact of food crop failure induced by drought, crop specific pests and/or diseases and thus contribute to the livelihood of the 180 million people in SSA, which are food insecure.

### *Introduction*

Pastoral systems in arid and semi-arid regions of Sub-Saharan Africa used to cope effectively and in an environmentally sustainable manner with the prevailing harsh and erratic ecological conditions of those regions. The ability to move their herds over large distances and take refuge in more favorable sites during droughts was critical to their livestock and livelihoods. Moreover, by maintaining the supply of animal food products during regional droughts, they mitigated the impact of simultaneous crop failures on food security in adjacent more humid areas. Unfortunately, mobility is increasingly being constrained by various developments, as described below, and the effectiveness of the pastoral system is deteriorating fast. As a result, pastoralists are now burdening rather than supporting larger societies. This note provides the rationale for investment in the recovery of mobility of these pastoral systems.



### *Key Sustainable Land Management Issues*

Mobile pastoral systems in arid and semi-arid regions make sustainable use of natural resources by “tracking” of climatic and landscape variability (Niamir-Fuller 2000). However, land degradation will occur when livestock is forced to stay year round in restricted areas. In semi-arid and adjacent sub-humid regions, land degradation is clearly linked to settlement and the combined effect of growing human populations and uncoordinated different land uses. For example in West Africa, uncontrolled expansion of low-input cropping systems, accompanied by uncontrolled bush fires, wood fuel collection, and increasing numbers of sedentary livestock, induces severe land degradation of both crop and rangelands (Leloup 1994). Hence, the notion that “overgrazing” or livestock holding in general would be the primary cause of desertification in Africa is no longer justified.

### *Trends of Resource Use*

During the last century, frequency and distances of herd movements have declined (e.g., Niamir-Fuller 2000), and various forms and degrees of settlement occurred. Spontaneous settlement is usually caused by long droughts, encroachment of other land uses (e.g., Cullis and Cathy 2004; Leloup 1994; Mkutu 2004), comparative lack of infrastructure and social services, disease control policies (e.g. Morton 2001), shifting ownership (Niamir-Fuller, 2000), breakdown of customary pastoral social hierarchies, and social insecurity (e.g., Morton, 2001). Governments are sometimes promoting settlement to intensify and commercialize animal production and facilitate social control and delivery of social and livestock specific services (Pratt et al. 1997). Involuntary settlement of pastoralists by governments has also been reported because of dam construction, famine, and civil war (Larsen and Hassan 2003).

Since about the 1920s, vast areas of natural rangelands in arid and semi-arid regions have been taken over by cropping systems, semi- and private livestock and game ranches, nature reserves, and infrastructure. The encroached rangelands included the better dry season grazing areas with easier access to water. They are the key resources ensuring the overall sustainability of the pastoral system.

### *Key Drivers*

The demands of growing human populations everywhere else have been driving the increasing competitive and conflicting use of arid and semi-arid regions.

For the longest time, the multiple values and needs of traditional mobile pastoralism have been neglected or misunderstood. Until the 1970s pastoralism was considered inefficient and backward, and livestock research and development focused on veterinary care and increasing beef productivity per animal. Only from the mid 1970s have field studies on pastoral systems emerged on seasonal livestock movements, herd-sex structures and productivity, rangelands ecology, and the multiple functions of pastoralism (Blench and Marriage 1999, Breman and de Wit 1983; de Ridder and Wagenaar 1984). The advantages of opportune and flexible use of natural resources, rather than controlling stocking rates, have been only recently accepted as the recommended scientific basis of livestock development (Behnke and Scoones 1993).

Policies have undermined basic foundations of pastoralism. Some examples are:

- The establishment of state boundaries which neglected the interest of local land use patterns and societies.
- A weak representation of pastoralists at the national level. Ministries in charge of livestock generally do not address issues of accessibility of natural resources or availability of social services (i.e., education, health care, and infrastructure).
- The use of inadequate land use policies and legislation that neglected existing customary tenure systems and undermined relevant local authorities, in particular with regard to the use of natural rangelands (Kirk 2000).
- The practice of unfavorable incentive policies. Dumping of beef, in particular by the EU and favored by African governments, reduced the income of West African pastoralists and caused them to take up arable farming. National government policies of subsidizing inputs have favored cropping systems over pastoral systems and fuel (Pratt et al. 1997). Moreover, subsidy of livestock ranching at the expense of rangelands for pastoralists and wildlife is still ongoing (Cullis and Watson 2004).

#### *Lessons Learned*

- Mobility of pastoral systems allows for coping with droughts and avoids natural resources degradation.
- Misunderstanding, lack of knowledge, and neglect of the effectiveness and needs of mobile pastoral systems in arid and semi-arid areas rather than changing environmental conditions and inherent malfunction of pastoral systems; explain the increasing degradation and downward poverty cycle.
- The multifunctionality of pastoral systems, such as the supply of live animals, milk, meat, manure, hides, transport and animal traction makes SSA's mobile pastoralist more productive than the US and Australian livestock systems under similar ecological environments (Bremen and de Wit 1983; de Ridder and Wagenaar 1984). Fodder supply is achieved by minimal labor and low economic cost, the chance of disease transmission between animals is low, and access to various markets and social communities and gatherings is easy (Niamir-Fuller 2000).
- The ecological, social and economic interests of mobile pastoralists have been too often overlooked.

#### *Opportunities for Sustainable Land Management*

Rather than a backward antiquated system, mobile pastoralism can be an efficient and sustainable system. Improving natural rangelands in arid and semi-arid regions would improve the world's carbon storage capacity, biodiversity, and water quality.

Arid and semi-arid lands represent about two-thirds of Africa's total land area of nearly 30 million square kilometers (UNEP 2000) -- hosting about 189 million people. The semi-arid and arid areas in the Horn make up 70 percent of the total land area, which provide an average of 20 to 30 percent of GDP, with substantial sub-regional trade (Little 1996). In West Africa, the pastoral sector contributes between 10-20 percent of total GDP in Mauritania, Mali, and Niger, and there is active trade between those countries. Pastoral development could, therefore, be an important force in regional development.

Support to mobile pastoralists would be of immediate benefit to the approximately 30 million pastoral peoples living in the arid areas (ILRI 2002) covering some of the most deprived populations in the region; and often remaining far removed geographically, linguistically, culturally, academically, and economically from those who run the country (Pratt and et al. 1997).

Mobile pastoralists are more than most other groups involved and are impacted by enduring social tensions often resulting from competition over natural resource uses. Such cases are of concern in transnational and national situations such as in Senegal/Mauritania, Cote d'Ivoire, Burkina Faso, Kenya/Somalia, Tanzania, Benin, Sudan (e.g., Shazali and Ahmed 1999; van Driel 2001). Pastoral development could, therefore, prevent some of the conflict or postconflict, social upheaval, and deprivation.

Enhancing the condition and availability of natural rangelands and water resources<sup>1</sup> for pastoral production would simultaneously improve wild food availability, provide critical micro-nutrients, and diversify regional rural economies. Moreover, increasing the area and condition of rangelands adjacent to cropping areas, would favor the sustainability and productivity of the cropping systems through reduced soil erosion because of increased water retention capacity of the rangelands and through increased availability of animal manure per cropping area unit. Finally, mixed crop-rangeland systems would reduce the impact of food crop failure induced by drought, crop specific pests and/or diseases and thus contribute to the livelihood of the 180 million people in SSA, which are food insecure (Ehui et al. 2002).

#### *Rationale for Investments*

The declining mobility, is leading sub-Saharan African pastoralists in a downward cycle of environmental degradation, poverty, and increased food aid dependency.

Standards of living are falling among the approximate 20 million mobile pastoralists in Africa; often resulting in settlement and the need to rely on alternative income sources, such as cropping and hired labor, out-migration toward urban centers or, ultimately food aid (Niamir-Fuller 2000). Absentee investors/owners are increasingly contracting pastoralists to herd their livestock, while often putting restriction to livestock movements to facilitate control (Fafchamps et al. 1996).

Per capita ownership of livestock is declining significantly and for many pastoralist families are now below the minimum subsistence level. In addition, production per livestock unit is declining. For example, over the period 1975-1995 beef production per animal declined slightly from 135 kg/head to 129 kg/head (Ehui et al. 2002).

Frequent and almost permanent relief interventions, in human food aid and feed supplements for livestock are the result (Morton 2001; Pratt et al. 1997). For example, in the Horn of Africa pastoralists represent usually the part of the national populations most food aid dependent. Based on the insights described earlier, investing in mobile pastoral development would address the following aspects of general interest to economic development of the arid and semi-arid areas of SSA:

- maintain efficient natural resource use in arid and semi-arid areas,
- support important sub-regional and national economies,
- reduce poverty,

- reduce social conflicts, and
- enhance food security.

### *Recommendations for Practitioners*

*Broad-based consultations and partnerships:* Raising awareness of all policy makers on national, subregional, and regional level is required to define the long-term vision on the role of mobile pastoral systems as a tool of sustainable natural resources management. Timing (i.e., letting it dovetail with the preparation of major policy papers, such as the Poverty Reduction Strategy Papers (PRSPs) and donor assistance strategies) and broad-based ownership (i.e., involvement of infrastructure and social service departments) would be essential, because of the crosscutting nature of the issues. Adequate representation of pastoralists in defining a long-term vision and the subsequent follow-up will be critical. The ALive program, with its website, facilitates communication among various stakeholders.

*Research:* Monitoring activities need to be supported to fill the gaps in knowledge on a country –by-country base of their specific situation (e.g., total number of pastoralists and their livestock, importance of absentee owners, benefits and costs to national economy, physical constraints to mobility, policies constraining mobility, pastoral organizations). Meanwhile, adequate indicators to monitor the situation of mobile pastoralism and its role in larger economies need to be defined and subsequently long term measurement arranged. Research should also assess the lessons learned available in the literature regarding various attempt to improve the situation (e.g. water use fees, grazing fees, livestock corridors, integrated livestock-wildlife management, integrated livestock-forest management, grazing reserves) while attempting to produce “out of the box” new incentives to be tested.

*Incentive policies:* Public funds and mechanisms need to be used to support the viability and mobility of pastoral systems, such as by introducing countervailing import tariffs on meats and limiting distribution of subsidized livestock feed. Provision of livestock feed causes declining mobility, induces long-term dependency and abuse of systems, often reaching only the more sedentary and wealthy livestock owners (Hazell 2000). Water use fees would improve sustainability of water infrastructure and cause better spatial distribution of livestock. Toleration of livestock in nature reserves may also be a viable option to enhance mobility.

*Resource access policies:* The development of appropriate legislation, ensuring access and user rights (not necessarily property rights) to critical grazing and water resources, to limit encroachment of other uses and users (e.g., cropping and ranching), integrate various natural resources uses and users, and in some areas, reclaim some of the lost key grazing and water resources for pastoral use is critical, and, although highly sensitive, absolutely essential for environmentally and socially sustainable development of these areas. Where increased cropping and declining stock numbers have made the long migration impossible, shorter treks, with a closer integration of crops and livestock is probably the best strategy, with community institutions facilitating and enforcing contracts between the different land uses and users.

*Infrastructure* Infrastructure needs concern mostly water, networks of pathways through crop areas, markets and mobile communication and weather forecasting equipment to manage drought. Sustainability of these investments is a major issue, and needs to be addressed through clear agreements with pastoral users on cost sharing and maintenance responsibilities.

*Services:* Service needs concern the technical services such as veterinary care and livestock marketing information, and cover adapted social services such as health care and education. Investments include the equipment and training needs to replace the current static service models for human and animal health and education with mobile service models. Major strategic decisions are required in education on the curriculum (focus on pastoral indigenous knowledge, versus more formal teaching, language) and “training the trainer” programs (Kratli 2001). In health the major strategic decision concerns the combination of human and animal basic health care system, which is often debated, has many synergies, but is rarely implemented.

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### **Web Resources**

[http://www.virtualcentre.org/en/ele/econf\\_03\\_alive/policy.htm](http://www.virtualcentre.org/en/ele/econf_03_alive/policy.htm)

### **ENDNOTE**

1. Natural rangelands and water resources contribute to many aspects of interest to economic and social development such as: biomass fuels, human and veterinary health care products, shelter materials, water transport, cultural values, and sometimes eco-tourism.

This Note was prepared by Susan Leloup. Consultant.



## **Investment Note: Sustainable Land Management in Marginal Dry Areas of the Middle East and North Africa: An Integrated Natural Resource Management Approach**

### *Summary*

The International Center for Agricultural Research in the Dry Areas (ICARDA) based in Aleppo, Syria has been working with farmers in the Middle East and North Africa region to develop innovative crop diversification alternatives for smallholder farmers. In marginal drylands of the Khanasser valley, the rural poor live between the traditional agricultural areas and the arid rangelands of <200 mm rainfall/year. Pressures on these lands are considerable, land holdings are shrinking in size, and land productivity is decreasing - with resulting increased poverty and out-migration.

In the past, promising technologies were not adopted because they were developed in isolation from the requirements of the local communities and were based on an inadequate understanding of the asset base and flows and local informal institutions. The study showed that knowledge sharing and increased public awareness of land degradation to facilitate closer cooperation amongst the stakeholders involved in sustainable land management resulted in options targeted at the various sectors of the population, each with different access to natural, physical, human and financial capital. And, while recognizing that income generation is the first priorities of the land users, most of the technological options also contribute to a more sustainable management of the land. The lessons learned in this pilot program are applicable more widely in the Middle East and North Africa region.

### *Key Sustainable Land Management Issues*

In marginal drylands of the Khanasser valley, the rural poor live between the traditional agricultural areas and the arid rangelands of <200 mm rainfall/year. The valley has agricultural and rangelands as its main habitats and extends over 450 km<sup>2</sup> with 58 villages with 5 to 270 households per village and a total population of approximately 37,000. Pressures on these lands include high population growth rates, erratic rainfall patterns and droughts, soil erosion from both wind and water, declining soil fertility, saline groundwater, lack of drought tolerant germplasm and alternative crop-livestock options, lack of credit and financial capital, lack of information on new technologies and farming practices, unclear land property rights and policy disincentives to invest in dry areas and a lack of market and market information. As a result of high population growth rates, land holdings are shrinking in size, and land productivity is decreasing - with resulting increased poverty and out-migration.

The farming systems are 'dryland rainfed mixed crop-livestock' and 'pastoral' systems as defined by Dixon et al., 2001. While agriculture is still the main activity based on extensive sheep rearing and cultivation of barley mainly for forage, livelihoods depend on both on- and off-farm income. Households in the Khanasser Valley can be categorized into three main groups (La Rovere et al, 2006);

- Agriculturalists who grow crops, fatten lambs, and undertake wage labor (about 40 percent of the households)
- Laborers who are semi-landless and mostly rely on on-farm earnings and migrations (50 percent of the households)

- Pastoralists who are extensive herders, migrating for wage labor, or occasionally engaging in intensive lamb fattening (about 10 percent of the households).

The main coping strategies of households living in these marginal areas, therefore, include diversification of livelihood strategies, intensification of agriculture, off-farm employment and exiting agriculture. This grouping immediately raises questions on who to target and with what. If the goal is primarily poverty alleviation, then interventions should focus on the poorest (laborers and pastoralists). If the goal is to expand food production, then the focus should be on agriculturalists. If the goal is to protect the land, the emphasis should be on the mainly government controlled communal rangelands and the privately owned cultivated land (land used mainly by pastoralists and agriculturalists).

The tool used to help orientate the project team was a simple analysis of the strengths, weaknesses, opportunities, and threats (SWOT) of the marginal dry areas. The input to the analysis came from contributions from land users, researchers, extension agents and decision makers. Table 3.11 summarizes the results of this exercise.

The study attempted comprehensively to address the complexity of this marginal dryland by identifying environmentally benign options that improve livelihoods, reduce poverty and sustain the natural resource base. An inter-disciplinary approach was taken to introduce new land use options and to broaden the interactions between local communities, researchers and local and national governments by creating multi-stakeholder platforms (Campbell et al., 2006).

#### *Lessons Learned from past experiences*

Firstly, an analysis was conducted of previous experiences. In the past, promising technologies were not adopted because they were developed in isolation from the requirements of the local communities and were based on an inadequate understanding of the asset base and flows and local informal institutions. It was clear that there was a need to study livelihood strategies in greater detail for better targeting of agricultural and non-agricultural interventions. Multi-stakeholder processes are required that bring together local populations and decision makers to develop common understandings of the different perceptions of these marginal zones and to facilitate better organizational ability of community-based groups. In addition, the time lag between the announcement of a change in restrictions to cropping on marginal lands and the implementation of the new regulations pointed to the need to improve communication between policy makers and land users.

**Table 3.11 Major strengths, weaknesses, opportunities and threats for the Khanasser valley as an example of marginal drylands**

<p><b>Strengths:</b></p> <ul style="list-style-type: none"> <li>• Indigenous knowledge and local innovations</li> <li>• Strong social networks and rich local culture</li> <li>• Comparative advantage for small ruminant production</li> <li>• Salt lake with rich bird biodiversity</li> <li>• Relatively unpolluted environment</li> <li>• Reasonable mobility and accessible markets</li> <li>• Improved basic services (electricity, roads, mobile phone network)</li> </ul>	<p><b>Weaknesses:</b></p> <ul style="list-style-type: none"> <li>• Cash flow problems (resulting in lack of long-term investments)</li> <li>• Poor nutritional status of children</li> <li>• Limited experience with non-traditional farming enterprises</li> <li>• Lack of adapted crop germplasm</li> <li>• Decreasing productivity</li> <li>• Degraded natural resource base (soil, groundwater, vegetation) and degrading management practices</li> <li>• Land degradation is 'masked' by variations in rainfall</li> <li>• Poor extension services</li> </ul>
<p><b>Opportunities:</b></p> <ul style="list-style-type: none"> <li>• Investments of off-farm income into productive resources</li> <li>• Better education levels and expertise</li> <li>• Increased awareness of the risks of resource degradation</li> <li>• Cooperatives</li> <li>• Improved market knowledge via mobile phones and other media</li> <li>• Out-migration and off-farm opportunities</li> <li>• Sheep fattening</li> <li>• Potential to improve the traditional barley system</li> <li>• Improved germplasm</li> <li>• Diversification for cash and subsistence purposes</li> <li>• Agro-, eco- and cultural-tourism</li> <li>• Runoff water harvesting and efficient small-scale irrigation systems</li> <li>• Soil fertility improvement</li> <li>• Rangeland rehabilitation and medicinal plants collection</li> <li>• Better government services and increased attention for poverty alleviation and environmental services in marginal areas</li> </ul>	<p><b>Threats:</b></p> <ul style="list-style-type: none"> <li>• Aging and feminization of the active Khanasser population</li> <li>• Declining social networks</li> <li>• Destruction of traditional 'beehive houses'</li> <li>• Increased population pressure and too small land holdings</li> <li>• Depletion of ground water resources</li> <li>• Recurrent droughts</li> <li>• Further decline of soil fertility and ground water levels</li> <li>• Declining ground water quality, and salinization of irrigated fields</li> <li>• Population by intensive sheep fattening and untreated village sewage</li> <li>• Degradation of the fragile Jabul salt lake eco-system</li> <li>• Unreliable export markets for sheep</li> </ul>

*Opportunities for Sustainable Land Management (products and services)*

Following this analysis, the team then proceeded to develop and refine a set of options that had been researched previously in the area. After on-farm trials the options were tried and tested jointly by researchers and interested land users who were organized into 'farmer interest groups' or FIGs on a voluntary basis. From this collaboration, the following feasible options were identified:

Options that strengthen the traditional farming system:

- New barley varieties selected by using a participatory breeding approach.

- Barley production with application of phosphogypsum to improve soil fertility, and to increase and stabilize production in dry years.
- Dairy products from sheep for consumption or sale.
- Seed priming of barley seeds with nutrient solutions to improve crop establishment.

#### Diversification options:

- Barley intercropped with Atriplex shrubs to stabilize forage production, increase biomass during dry years, and enhance protein content in sheep diets.
- Improved vetch production by selected drought-tolerant varieties to reduce production risks.
- Improved management of rainfed cumin (a new cash crop) to stabilize and increase production and improve its marketing value.
- Olive orchards, with water harvesting and cultivated on hill foot slopes, to increase production and reduce summer irrigation by groundwater.

#### Intensification options:

- Improved lamb fattening by using lower-cost feeds.

#### Institutional options:

- Traditional dairy institutions (*Jabban*) for knowledge sharing and informal credit provision.
- Village saving and credit associations (*Sanadiq*, established and operated by a parallel development project led by UNDP).

#### *Rationale for Investment*

The marginal zone of Syria represented by this case study covers around 11 percent of the country's land area and 14 percent of the population (about 2 million people). Poverty is greatest in areas located within this zone. The fact that many men migrate to urban areas results in labor shortages and in socio-cultural decline from the loss of social structure and cultural heritage. Investments are needed to restore both the social and physical infrastructures, and to reverse land degradation. This last is a slowly changing variable not perceived as urgent by local populations but is a process that threatens long-term sustainability of the region. Importantly, this approach can be applied (with local adaptations) across large areas of North Africa, Iraq, Iran, Jordan and Central Asia which are characterized by similar agro-ecological and socio-economic factors.

#### *Recommendations for Practitioners*

The study showed that knowledge sharing and increased public awareness of land degradation will be required in order to facilitate closer cooperation amongst the stakeholders involved in sustainable land management. As a result of closer integration amongst all stakeholders, a set of options were developed by the study team. These are targeted at the various sectors of the population, each with different access to natural, physical, human and financial capital. And, while recognizing that income generation is the first priority of the land users, most of the technological options also contribute to a more sustainable management of the land. The study also demonstrated to government

researchers, extension agents and land users the value of collaboration. Consequently, plans are underway to replicate the example of the Khanasser valley to similar areas in Syria.

For each crop enterprise, specific technological objectives have been identified along with a corresponding agronomic approach. A summary of those objectives and approaches taken to introduce technological interventions is shown in Table 3.13 (modified from La Rovere et al., 2007).

**Table 3.13 Technological interventions introduced into the Khanasser Valley**

<b>Enterprises</b>	<b>Objective of technology</b>	<b>Approach</b>
Barley (rainfed)	Stabilize and enhance barley productivity	Selection and improvement of barley varieties using a farmer-breeding participatory approach
Barley (rainfed)	Stabilise feed production, increase dry year biomass, enhance protein content	Intercropping with the Atriplex (saltbush) shrub for being grazed by sheep
Barley (rainfed)	Improve soil fertility, increase and stabilize production in dry years	Application of a phosphogypsum amendment residue of the fertilizer industry
Wheat (irrigated)	Improve rainfall water productivity and yields	Supplemental irrigation using sprinkler and surface methods
Vetch	Reduce production risks, increase feed availability	Inclusion of improved drought-tolerant vetch varieties into traditional rotations
Cumin (rainfed)	Stabilise and increase production and improve its marketing outcome	Improved management
Olive Orchards	Increase olive production and reduce groundwater use for irrigation	Olive trees cultivated on foot hills, through using water harvesting practices
Sheep (lambs)	Intensify production	Lamb fattening by using lower-cost feeds
Sheep (extensive)	Enhance home consumption and sale of dairy surplus	Improvement of small-scale dairy sheep institutions and strategies (e.g. for marketing)
Sheep (dairy)	Improve sheep productivity	Various small ruminant technologies (e.g. health, productivity)
Water harvesting	Improve water use efficiency; protect natural resources	Combine with olive orchard management
Phosphogypsum applications	Restore soil fertility	Combine with barley crop improvements

For all these technologies and options, feasibility reports were prepared including an *ex ante* economic analyses (La Rovere and Aw-Hassan, 2005; La Rovere et al., 2007). But this was taken further by the study team – the options were further analysed based on the characteristics of the different livelihood categories and assets of the defined population groups. Thus the options were categorized into those that are:

- profitable in the short term and which require more awareness and information,
- profitable, but that require investment and are prone to climatic risks,
- highly profitable but which need high investments, and

- profitable only in the long run, and need initial investment.

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## Web Resources <<all caps, bf, flush left>>

<http://www.icarda.cgiar.org/INRMsite/index.htm>

[http://www.icarda.cgiar.org/INRMsite/Navigating\\_amidst\\_complexity.pdf](http://www.icarda.cgiar.org/INRMsite/Navigating_amidst_complexity.pdf)

[http://www.icarda.cgiar.org/INRMsite/Towards\\_INRM.pdf](http://www.icarda.cgiar.org/INRMsite/Towards_INRM.pdf)

[http://www.idrc.ca/en/ev-103297-201-1-DO\\_TOPIC.html#begining](http://www.idrc.ca/en/ev-103297-201-1-DO_TOPIC.html#begining)

[http://www.idrc.ca/en/ev-97782-201-1-DO\\_TOPIC.html](http://www.idrc.ca/en/ev-97782-201-1-DO_TOPIC.html)

[http://www.idrc.ca/en/ev-84706-201-1-DO\\_TOPIC.html](http://www.idrc.ca/en/ev-84706-201-1-DO_TOPIC.html)

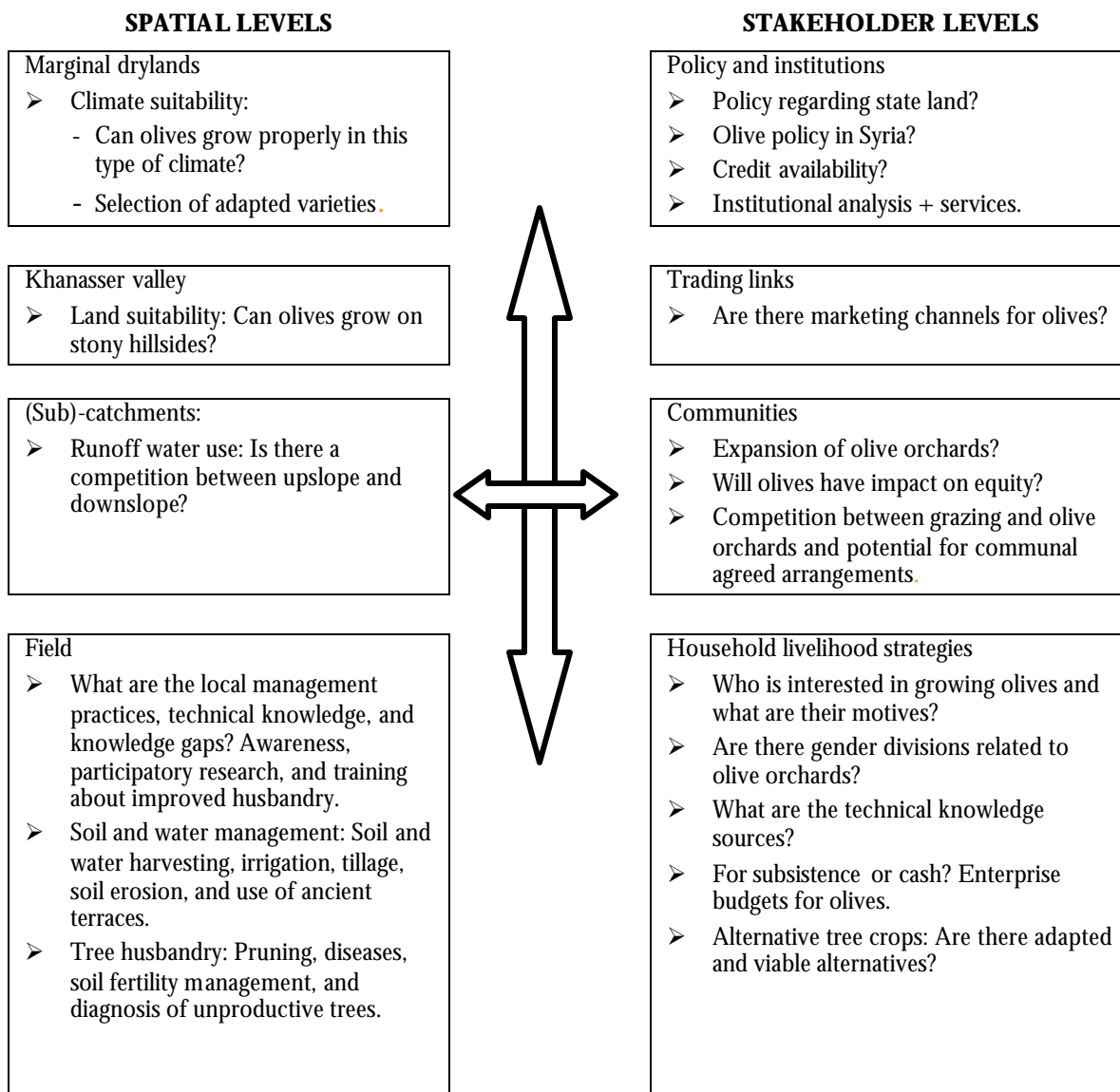
[http://www.idrc.ca/en/ev-34000-201-1-DO\\_TOPIC.html](http://www.idrc.ca/en/ev-34000-201-1-DO_TOPIC.html)

This Note was prepared by Richard Thomas, F. Turkelboom, R. La Rovere, A. Aw-Hassan, A. Bruggeman, ICARDA.

## ANNEX 1

To help determine the main driving variables a toolbox approach was taken that comprises diagnostic, problem solving, and process tools (Turkelboom et al. 2004). An example of a multi-level analytical framework to identify the main constraints on the hill slopes of the valley is presented in Table A1. Biophysical and socioeconomic factors are examined in a framework consisting of a “spatial pilla” and a “stakeholder pillar” that are linked both vertically and horizontally. The tool lists the main prioritized issues that constrain the adoption of technologies and resources and identifies potential solutions. This simple framework requires a multidisciplinary approach and helps foster greater understanding and communication among all parties.

**Table A1. Application of the multilevel analytical framework (MLAF) to the management of olive orchards on hill slopes at Khanasser valley.**



Source: ICARDA.



## **Innovative Activity Profile: High Value Cash Crops for Semi-arid Regions - Cumin Production in Khanasser, Syria**

### *Summary*

Cumin is an innovative cash crop in the Middle East and North Africa region that requires relatively little land, water and soil nutrients because of its low biomass. Farmers are attracted to it because of these low input requirements and its relatively short cycle of around 100 days. The International Center for Agricultural Research in the Dry Areas (ICARDA) based in Aleppo, Syria has been working with farmers to develop innovative crop diversification alternatives for smallholder farmers. This note shows the potential for introducing a reliably profitable cash crop into a conventional monocropping system in an area of low rainfall. Cumin provides a profitable rotation crop for poor farmers reliant on barley cash crops. The requirements of the new crop were carefully investigated so as to ensure that it made a consistent and reliable alternative.

### *Presentation of Innovation*

Currently cumin is the only rainfed cash crop available for Khanasser farmers as an alternative to barley mono-cropping. Preliminary results indicate that yields of barley after cumin are more sustainable compared with barley mono-cropping and there is residual water available for the following barley crop. When grown under supplemental irrigation, cumin requires less water than wheat. The inclusion of cumin contributes to diversification of the cropping system and farm income and manual weeding and harvesting of the crop generates local employment opportunities.

### *Project Objective and Description*

Cumin is a cash crop with a short growing cycle, and demands little moisture and nutrient inputs. Cumin is suitable for households with even small amounts of agricultural land. However, they will need to have enough family labor.

Proper agronomic management reduces the risk for farmers: Some suggested management practices include:

- (i) Planting in mid-January.
- (ii) Mixing seeds and fertilizer, and planting them together (using cereal drill).
- (iii) Seed rate of 30 kg/ha.
- (iv) Fertilizer rate:
  - At planting, 50 kg/ha of Triple Super Phosphate (TSP) and 50 kg/ha of urea.
  - If spring rains are adequate, 50 kg of Ammonium Nitrate (33 percent) can be top-dressed.
- (v) Weed control:
  - Hand weeding at early stages of cumin growth.
  - Herbicide application of Treflan 15 days before planting and Afalon or Gesagard early postemergence would provide proper weed control.

### *Benefits and Impacts of the Activity*

Cumin provides an alternative rainfed cash crop with acceptable yields ranging from 50-1,000 kg/ha with averages around 250kg/ha. Gross income per season is around 28,990 Syrian Lira/ha (US \$576/ha) with a net annual profit of around 16,245 SL/ha (US \$323/ha). Yields and profits are higher if the crop is irrigated. It has the advantage that only small land areas of 0.08-1.6 ha are required for profitable activities, however, this varies with fluctuating market prices.

### *Lessons Learned and Issues for Scaling-up*

- High cost for inputs.
- Good management knowledge is needed to obtain good returns and reduce risks of failure.
- Cumin planted in succession is susceptible to the build up of cumin wilt disease (but this disease does not affect the following barley crop).
- Fluctuations in cumin prices make the profits from growing cumin uncertain – but during the period studied prices always remained above the minimum profitability thresholds (and have recently improved).
- Cumin prices remain competitive even in marginal areas, although they depend on international trade and need to be monitored closely.
- Farmers need to have better access to early market and price information. They need this information before they make planting and/or marketing decisions.
- Management recommendations that reduce production risks should be transferred to farmers through local extension services and farmer interest groups.

### *Economic Assessment*

On rainfed production systems the investment cost is currently US \$248/ha with a net return on capital of 106 percent. Net return on land is estimated at US \$263/ha, on hired labor at 0.05 and on family labor 0.17. It is attractive to farmers because of low water requirements, its short duration, and its ability to directly contribute to household cash flow. Market price fluctuations represent a high risk.

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This Profile was prepared by Francis Turkelboom and Richard Thomas, International Center for Agricultural Research in Dry Areas (ICARDA).

## **Innovative Activity Profile: Economic and Sustainable Land Management Benefits of the Forage Legume – Vetch**

The International Center for Agricultural Research in the Dry Areas (ICARDA) based in Aleppo, Syria has been working with farmers to develop innovative crop, forage, and livestock diversification alternatives for smallholder farmers. The objectives of ICARDA's work on forage systems are to introduce leguminous forage species (e.g. vetch) into the farming systems of poor livestock farmers in rural and urban communities in order to improve production and make use of the nitrogen fixing ability of this legume on soils that have been depleted of nutrients and soil organic matter.

Vetch is an annual forage legume that is planted in rotation with barley in winter. It is either grazed or cut for haymaking in early spring. Vetch seed can be harvested in late spring. Similarly Vetch straw is produced in late spring and used as protein supplements to cereal straw for sheep meat and milk production. Vetch can be grown in dry areas with annual rainfall ranging from 200-400 mm although it is riskier than the more drought tolerant barley.

### *Presentation of Innovation*

Field experimentation with farmers have shown that yields of barley straw and grain increase by 25-40 percent when grown in rotation with Vetch, as compared with continuous barley cropping. In addition feeding Vetch hay or grain as supplement to low-quality cereal straw improves lamb growth by 20-30 percent. Lambs grazing Vetch in early spring gain as much as 100-150 g per day.

Soil fertility is increased mainly by way of increases in soil nitrogen and phosphorus by 10-15 percent when planted in rotation with barley. Additional income can be earned through the sale of vetch seed and straw. In comparisons with other tested options the production and marketing risks of vetch are lower than cumin and wheat. Investment cost is \$126/ha with a net return on capital of 160 percent and net return on land is \$202/ha.

### *Lessons Learned*

More information is required on the beneficial effects of Vetch on soil fertility over the long-term in order to increase the attractiveness of this option. Agronomic management can be improved considerably by paying more attention to seeding rates and planting methods. Farmers need access to better storage and utilization practices of Vetch hay, and would benefit from reduced costs of weeding. Vetch appears to fit well within the diversification strategies used by farmers under mixed or intensive systems.

### *Issues for Scaling-up: Investments*

Future research on Vetch should include efforts to empower farmers to use the technology, and improve the establishment and harvest of the crop. Greater support is required to establish and maintain viable forage seed systems. This can be done by paying more attention to the creation of market opportunities for fodder and forage seed. Efforts are required to improve seed quality of high-yielding varieties and make these more readily available to farmers.

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This Profile was prepared by Richard Thomas, Francis Turkelboom, and Roberto LaRovere, ICARDA.

## **Innovative Activity Profile: Participatory Barley Breeding Program for Semi-Arid Regions**

In a conventional crop breeding program, the most promising lines are released as varieties, their seed is produced under controlled conditions, and only then farmers decide on adoption. The process often results in many varieties being released, and only a few are adopted. The International Center for Agricultural Research in the Dry Areas (ICARDA) based in Aleppo, Syria has been working with farmers to develop innovative crop, forage, and livestock diversification alternatives for smallholder farmers.

The Decentralized-Participatory Plant Breeding (D-PPB) approach pioneered by ICARDA focuses on an alternative way of conducting plant breeding that is more efficient in bringing new varieties to farmers regardless of their farm size, location, wealth, or education. These varieties are adapted to the physical and socioeconomic environment. The component activities include: (a) training of farmers, researchers, and extension staff; (b) field trials, (c) seed production, and (d) dissemination workshops and publications.

### *Presentation of Innovation*

The major consequence of D-PPB concepts is that the process turns the delivery phase of a plant-breeding program upside down. The program is based on the following concepts:

- The traditional linear sequence: scientist-extension-farmers is replaced by a team approach with scientists, extension staff, and farmers participating in variety development.
- Selection is conducted in farmers' fields using agronomic practices decided by them.
- Farmers are the key decision makers.

The general scheme starts with planning meetings where farmers assist in the design of a research agenda in which they will participate. Under D-PPB, it is the initial farmers' adoption that drives the decision of which variety to release. Hence, adoption rates are higher, and risks minimized, as intimate knowledge of varietal performance is gained as part of the process. The investment in seed production is nearly always paid off by farmers' adoption.

### *Benefits and Impacts of the Activity*

Agriculturalists and land-poor laborers are benefiting from the quicker access to improved barley varieties as a result of D-PPB. Indirectly, pastoralists and their sheep herds benefit from better barley. The cyclic nature of D-PPB programs has enriched farmers' knowledge and improved their negotiation capability, thereby, empowering farming communities. Key project benefits include:

- Improved varieties are released quicker and adoption rates are higher.
- Different varieties are being selected in different areas in Syria, in direct response to different ecological constraints.
- Farmers spontaneously tested new varieties as early as three years after starting the program. Thousands of hectares are planted with two newly released varieties, and about 30 varieties are under large-scale testing.

- In advanced yield trials in the valley, several lines out-yielded the local varieties; yield gains were modest in Mugherat (10-11 percent), and higher in Khanasser (22-28 percent).

Farmers in Mugherat and Khanasser selected tall varieties and varieties that grow faster in winter. The visual selection of farmers in Mugherat was more closely correlated with grain yield ( $r = 0.503$ ) than that of farmers in Khanasser ( $r = 0.059$ ).

#### *Lessons Learned and Issues for Wider Application*

- Farmers are excellent partners: their contribution to the program increases together with their understanding of the process which becomes more and more demand-driven
- The quality of participation is unrelated to culture, religion, education, age, wealth, or gender.
- As the program develops, the breeder becomes more and more a facilitator and a provider of genetic variability.
- PPB increases crop biodiversity, promotes the use of landraces and wild relatives, and is ideal for organic conditions.
- In the case of Syria (the only country where a detailed study was conducted) the cost/benefit ratio of participatory plant breeding is less than half (.38) than conventional plant breeding.
- Participatory plant breeding offers the possibility of improving more than one crop within the same program (one of the first requests of farmers across many countries).
- Participatory plant breeding allows quick response to both agronomic and climatic changes.
- Participatory plant breeding is a good entry point (easy to organize) for integrated participatory research.
- Participatory plant breeding is a good training ground for future plant breeders (PPB in universities curriculum).

#### *Issues for Scaling-up: Investments*

In several countries, D-PPB generated changes in the attitude of policy makers and scientists toward the benefits of participatory research. At the same time, variety release systems are considered too rigid.

Extension services need to take on new tasks. The role of extension in D-PPB is in participating together with farmers and researchers, in technology development, and in involving additional farmers in the process, rather than transferring research results from researchers to farmers.

The difficulty for some National Program scientists to deal with farmers as partners is an ongoing concern. Changes within the national agricultural research and extension systems are slow.

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This Profile was prepared by S. Ceccarelli and S. Grando, ICARDA.



## **Innovation Activity Profile: Climate Risk Management in Support of Sustainable Land Management**

### *Summary*

Changes in climate patterns, such as the ones projected by climate change scenarios for many parts for the developing world, have the potential fundamentally to change current land management practices and alter the risk profile of agriculturally-based economies. Thus today, with the additional increasing commercialization and expansion of agriculture and the integration into international markets and supply chains, new risk management approaches that are adapted to the agricultural and rural sectors in developing countries and the pervasive risks affecting those sectors are required. In this note, the fundamental elements of a climate risk management approach for agricultural systems are outlined.

### *Introduction*

Farming and land management activities are exposed to seasonal climate risks arising from inter-annual climate variability and anthropogenic perturbations of the climate system, which are likely to result in more frequent extreme weather events. A key element of agricultural and rural risk management includes the efficient use of inherently variable natural resources (e.g., runoff), and measures to increase the resilience of land and crop management systems against seasonal climate threats (e.g., droughts, floods). Unmitigated risks are likely to result in increased crop and yield losses and in extreme cases in loss of the natural resource base (e.g., soil erosion).

Land management practices and agricultural expansion can alter (increase or decrease) the exposure to natural perils and the potential impacts associated with them. Extreme climatic events can result in irreversible damages to land management and farming systems, and, by extension, human livelihoods. Coping strategies of rural and agriculturally-based communities in response to such events often lead to unsustainable land management practices. For instance, after cyclones destroyed vanilla plantations in Madagascar in 2004 many rural communities turned to shifting cultivation infringing on protected areas and causing soil erosion. Thus, sustainable farming, of which risk management is an important component, is essential to sustainable land management and the preservation of the natural resource base.

Longer-term changes in climate patterns, such as the ones projected by climate change scenarios for many parts for the developing world, have the potential to fundamentally change current land management practices and alter the risk profile of agriculturally-based economies. These changes represent an additional layer of risk and uncertainty, and need increasingly be considered as part of a sound climate risk management framework.

### *Project Objective and Description*

Agricultural actors in developing countries, including commercial producers and smallholder farmers, rural communities, suppliers, traders, and planners have long dealt with the risks in agricultural production and have adopted traditional and *ad hoc* means to cope with them. At the same time, with increasing commercialization and expansion of agriculture and the integration into international markets and supply chains, risk patterns and exposure can change dramatically and

require risk management approaches that are adapted to the agricultural and rural sector in developing countries and the pervasive risks affecting it.

The Commodity Risk Management Group (CRMG) has worked with partners in several countries in Africa, Latin America, and Asia with the objective to assist agricultural producers and farmers, rural lending institutions, and governments in developing means to (a) identify, (b) quantify, and (c) manage risks arising from both market-forces (e.g., commodity price volatility) as well as from climatic events, such as seasonal droughts, floods, and storms. With respect to land management systems, the overarching objective of the risk management includes the protection of agriculturally-based livelihoods, the sustainable use of natural assets (e.g., soil, water, plant-genetic material), and the management of undesirable outcomes from climate-related stress (e.g., plant diseases).

Although markets can have a long-term effect on the development of land management systems through trade and commodity prices (thereby altering risk profiles); seasonal variations in climate, in particular extreme events, tend to have more direct effects on the natural resource base and agricultural assets. This note focuses mostly on risks arising from seasonal weather variability and extreme events. The fundamental elements of a climate risk management approach for agricultural systems are outlined below, and include several novel technologies and approaches toward managing long-term and seasonal climate risks.

#### *Presentation of Innovation*

The development of risk management solutions requires a systematic and step-wise approach. The principal framework for risk assessments in the productive sector includes risk identification, risk quantification, and the design of risk management instruments.

- (1) *Risk Identification*: Several perspectives may be chosen to identify risks affecting agricultural production:
  - a. *Spatio-temporal*: Identify the regions or locations that are affected by climatic stress and the season during which these stresses have the most significant impacts.
  - b. *Supply-chain*: Identify the elements in an agricultural supply chain in which value-added is at risk because of variability in climate. Additional risks in a supply-chain may arise directly or indirectly from weather perturbations, such as diseases and product quality, and from logistical and operational disruptions.
  - c. *Institutional*: Identify the operations or assets of institutions that are at risk, such as the lending portfolio of a micro-finance institution, or the delivery of goods and services (e.g., business interruption for input suppliers).
  
- (2) *Risk Quantification*: Once risks and their systemic linkages have been identified, the potential losses arising from such risks need to be quantified. In a quantitative risk, modeling framework risk is commonly defined as a function of (a) the climate or weather hazard, (b) the exposure of agricultural assets to natural hazards, and (c) the vulnerability of these assets to such hazards. Specifically,
  - a. *Hazards* are described by their spatial and temporal statistical properties (e.g., likelihood of cyclones of a certain strength making landfall in a particular location).
  - b. *Exposure* describes the absolute amount of assets (e.g., plantations) and economic activity that may experience harm because of the effects of natural events.
  - c. *Vulnerability* (or sensitivity) captures the degree to which assets and productive activities are susceptible to experience negative impacts of natural hazards.

This breakdown of risk is important as it illustrates that risk can arise from (a) temporary or permanent changes in hazard patterns (e.g., climate cycles), (b) changes in the exposure (e.g., agricultural expansion and intensification), and (c) changes in the vulnerability profiles (e.g., crop choices). That is, risk can be most effectively reduced by managing the exposure and reducing the vulnerability (increasing the resilience) of land management systems, whereas it is more difficult to change hazard patterns that are largely controlled by climatic processes.

(3) *Risk Management*: Lastly, appropriate risk management mechanism need to be developed to reduce (mitigate), transfer or share the residual risk. The appropriate management solution is a function of the (a) magnitude of the risk, (b) the likelihood with which a negative outcome may be realized, (c) institutional (informal or formal) capacity to cope with the risk, and (d) the nature of the underlying hazard (e.g., droughts represent a covariate risk that tends to affect large area simultaneously and generally results in long-term and indirect losses, whereas floods tend to be more localized and cause direct damage to crops and infrastructure such as irrigation systems).

Several existing and new technologies have been used and piloted in recent years to support risk modeling and management in developing countries. These include (a) geo-information technologies, such as space- or air-borne remote sensing, cyclone and flood modeling, (b) probabilistic and quantitative risk modeling, and (c) innovative approaches to transfer (insure) risk through market-based approaches. These innovations can enhance and complement more conventional approaches to risk management in the productive sectors, such as water storage, crop diversification, or flood mitigations schemes. Some of these innovations are featured in this note in relation to the risk framework described above.

- (1) *Remote sensing technologies* can provide cost-effective and rapid means to collect hazard information. Satellite-based sensors provide repeated observations of atmospheric and terrestrial conditions and can cover large geographic areas with moderate resolution sensors or small areas with very high spatial resolution. Examples for applications of remote sensing technology include (a) flood mapping and detection, (b) measurement of tropical rainfall, (c) monitoring of vegetation and crop conditions, and (d) cyclone tracking. Although remote sensing technology provides a very powerful tool in many risk applications, a key limitation is that it is a relatively new technology that provides limited historical observations, which are critical in modeling the long-term patterns of climatic hazards (for some sensors reliable time series are available from the mid 1980s, however the more advanced technologies provide generally less than 10 years of temporal observations).
- (2) *Bio-geophysical and atmospheric models* are frequently used when direct observations of hazards are not available. Careful calibration of models allows the simulation of hazard patterns over a longer-time period, which is critical to quantify trends and return periods of extreme climate events, such severe droughts or floods. Examples of state-of-the-art modeling in support of hazard analysis include (a) flood plain and inundation using numerical water balance and drainage model, (b) cyclone models that dynamically simulate the trajectories and wind speed of cyclones, and (c) regional circulation models that can be use to simulate seasonal climate patterns and provide seasonal forecasts.
- (3) *Risk models* combine the information about hazards in a probabilistic framework with information about the vulnerability and exposure of assets to estimate the likely damages and financial losses arising from extreme climatic events. Advances in geo-information technology, such as geographic information systems (GIS), facilitate the assimilation and

analysis of hazard, vulnerability, and financial models in an integrated framework. Many of these systems have become user-friendly and can be deployed on desktop computer systems to be used in an interactive and dynamic fashion by decision makers in support of risk assessment and management.

- (4) *Innovative approaches for risk transfer*: Agricultural insurance is lacking in most developing countries. Traditional Multi-Peril Crop Insurance (MPCI) programs, which compensate farmers based on yield loss measured in the field, have major drawbacks because of (a) adverse selection: farmers know more about their risks than the insurer, leading the low-risk farmers to opt out and leaving the insurer with only bad risks; (b) moral hazard: farmers' behaviors can influence the extent of damage that qualifies for insurance payouts; and (c) high administrative costs especially in small farmer communities, and difficulties of objective loss adjustment.

As a result, there has been a strong movement to develop index-based insurance solutions which demonstrate several advantages over MPCI. Index-based insurance products are contingent claims contracts for which payouts are determined by an objective parameter such as rainfall, temperature, and regional yield level that is highly correlated with farm-level yields or revenue outcomes. Farmers with index contracts receive timely payouts because the compensation is automatically triggered once the chosen index parameter reaches a prespecified level. The automatic trigger reduces administrative costs for the insurer by eliminating the need for tedious field-level damage assessment, while the objective and exogenous nature of the index prevents adverse selection and moral hazard. Index products are most suitable for covariate risks, (risks affecting larger areas or groups of people simultaneously), and most index product development to date has concentrated on rainfall deficit (i.e., drought), which is particularly difficult to insure by traditional insurance methods.

#### *Benefits and Impact of the Activity*

There are several benefits of following a systematic approach to assess risks in the productive sector in relation to sustainable land management, and applying the specific technologies described above. The benefits of systematic risk assessment and modeling include:

- The disaggregation of risk into hazard, vulnerability, and exposure provides a clear framework under which experts from different disciplines can collaborate on risk assessments, including climate experts and meteorologists, social scientists, engineers, or agronomists. In addition, it defines a clear functional relationship between natural hazards and the negative outcomes of risk.
- A clear risk management framework identifies the areas where investments would have the highest marginal impact to reduce risk. For instance, systematic risk modeling reveals how increasing exposure (e.g., agricultural expansion in flood plains) contributes to the overall risk compared to the vulnerability arising from poor farming practices.
- A risk management framework is scalable and the same general framework can be employed with varying geographic and sectoral detail. That is, simple risk models can be developed when data availability and quality are an issue, and more detailed and sector-specific models can easily be incorporated if appropriate data is available.
- Quantifying and mapping risks has an important awareness-raising effect as risks are frequently not explicitly addressed. Risk assessments can provide a powerful tool to

introduce measures to manage risks *ex ante*, that is, before damages and losses occur, rather than *ex post* after a disaster and severe event.

- Climate risk management provides a framework to promote new technology, such as better computer-based land monitoring systems, and build capacity for public and private-sector entities, such as planning departments or the domestic insurance market.

### *Lessons Learned and Issues for Wider Application*

- Good data is the most critical input for any risk modeling. Unfortunately, adequate data is rarely found in most client countries or poor data management systems prevent the data from being readily used. Despite sophisticated satellite technology and models, there is no substitute for high-quality data collection on the ground by agencies such as hydro-meteorological services and statistical bureaus. In many countries, in particular Africa, the capacity to collect data on natural hazards, including weather data, is deteriorating rapidly. Investments in hydro-meteorological infrastructure and data management systems are fundamental to support climate risk management, which is virtually impossible without solid data and statistical capacity at all administrative levels.
- Readily available public data sources, such as the ones derived from satellite data, could be used more effectively by national and local agencies. Capacity building in technical agencies, such as the agro-meteorological services, has the potential to unlock the wealth of under-used data sources that can generate a variety of public goods.
- Simple hazard and risk assessments can be performed in most countries by compiling data from existing sources (e.g., land use inventories, climatological times series etc.) and integrating them systematically in a common framework (through spatially-reference data layers in a geographic information system). This can provide a powerful starting point to engage local agencies and stakeholders, and stimulate more focused sector- or asset-specific risk analyses.
- Insurance markets in the productive sectors, in particular agriculture, are largely underdeveloped in most client countries. Index-based insurance products based on quantitative risk modeling, can potentially provide more adapted risk management solutions for the agricultural sector in developing countries. To deploy them effectively, however, requires capacity building in the domestic insurance sector, leveraging of local capacity to model risk, investments in sustainable data collection and management systems, and risk education and sensitization among stakeholders (e.g., producers, suppliers, and lending institutions in a agricultural supply chain).

## *Investment Needs and Priorities*

Key investments for better climate risk management include:

- Upgrading of hydro-meteorological infrastructure, including synoptic weather stations, river-runoff and surface water gauging stations, and agro-meteorological sites. This is a fundamental investment and requires a long-term perspective, including the development of institutions and agencies that have the mandate and resources to manage such systems and create value-added through dissemination of climate information.
- Capacity building at national and below-national level to collect, manage, disseminate, and use data for climate and disaster risk management, including basic training of technical staff, development of risk assessment protocols (before and after seasonal events), and statistical capacity.
- Development of multisector risk management frameworks that clearly delineate and facilitate public and private sector responsibilities in risk management, including insurance through market-based instruments and disaster response by public entities. A key element of such a framework is effective multilevel and multisector stakeholder coordination.
- Systematic development and updating of baseline data and natural hazards and risks arising from them. This would include the development of land management information systems, with routine inventories of the natural resource base, inventories of the key assets in the productive sectors, and updating of vulnerability profiles using some of the technologies described in this note.
- Improvement of rural infrastructure and capacity include hard solutions such as transportation, water storage facilities, information and communication infrastructure, drainage and irrigation systems, and soft solutions such as market development and diversification, community-driven risk management plans, or capacity extension services.

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## **Web Resources**

Agriculture and Rural Development Department (ARD) Commodity Risk Management Group (CRMG) 2006: *Managing Agricultural Production Risk*: [www.itf-commodityrisk.org]

Dartmouth Flood Observatory: [http://www.dartmouth.edu/~floods]

Developing Index-Based Insurance for Agriculture in Developing Countries:  
<http://www.un.org/esa/sustdev/publications/innovationbriefs/no2.pdf>

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## **Innovative Activity Profile: Land Degradation Surveillance: Quantifying and Monitoring Land Degradation**

### *Summary*

Diagnostic surveillance approaches used in the public health sector can now be adapted and deployed to provide a reliable mechanism for evidence-based learning and the sound targeting of investments in sustainable land management programmes. Initially a series of case definitions are developed through which the problem can be quantified. Then sample units are screened to determine whether they meet the case criteria. This involves conducting prevalence surveys requiring measurement on a large number of sample units. The land management surveillance approach uses a combination of cutting edge tools such as satellite remote sensing at multiple scales; georeferenced ground sampling schemes based on sentinel sites; infrared spectroscopy for rapid, reliable soil and plant tissue analysis; and mixed effects statistical models to provide population-based estimates from hierarchical data.

The framework provides a scientifically rigorous framework for evidenced-based management of land resources, modeled on well-tested scientific approaches used in epidemiology. The approach provides a spatial framework for testing interventions in landscapes in a way that samples the variability in conditions, thereby increasing the ability to generalize from outcomes. The baseline that the protocol generates provides a scientifically rigorous platform for monitoring impacts of intervention projects at a landscape level. The approach is particularly well suited to providing high quality information at low cost in areas such as sub-Saharan Africa, where existing data on land resources are sparse. It is being used in a UNEP capacity-building project to guide strategies for land restoration in five West African dryland countries and in a World Bank-GEF project in Kenya, led by the Kenya Agricultural Research Institute, which is designed to tackle land degradation problems in the Lake Victoria basin. Soil health surveillance has been recommended as part of a NEPAD-endorsed strategy for saving Africa's soils and is proposed for Sub-Saharan Africa as a component of the Global Digital Soil Map of the World project.

### *Introduction*

Many of the problems associated with managing land stem from the fact that there is a lack of systematic and operational approaches for assessing and monitoring land degradation at different scales (village to global). As a result, there is no mechanism for sound targeting of interventions and no basis for reliable evidence-based learning from the billions of dollars that have been invested in sustainable land management programs. Recent scientific and technical advances are enabling diagnostic surveillance approaches used in the public health sector to be deployed in sustainable land management. Land degradation surveillance provides a spatial framework for diagnosis of land management problems, systematic targeting and testing of interventions, and assessment of outcomes.

Some key questions are being asked by a broad range of stakeholders, such as regional and national policy makers, donors, environmental convention secretariats, and civil society. These questions are:

- What is the state of the nation's land at a particular point in time?



- How much agricultural land in sub-Saharan Africa is currently suffering from productivity declines and off-site impacts attributable to soil degradation?
- What caused the degradation in places where it exists, and how can further degradation be prevented?
- Can land degradation be reversed, and if so, what are the costs to individuals and to society?
- Are there cost-effective and socially acceptable means for treating degraded lands to increase their productivity, while avoiding harmful side effects to the environment such as the pollution of surface waters and accelerated greenhouse gas emissions?

### *Project Objectives and Description*

As surprising as it may seem, the world does not have clear answers to these questions at present. Our basic premise is that you cannot manage a problem without being able to measure progress from a baseline toward a well-defined target. Thus, a land health surveillance system must:

- Provide high spatial resolution, practical, timely, and cost-effective information about where specific land degradation processes occur in a given region or country, and how these are changing over time.
- Identify areas at risk of degradation and the commensurate preventive measures in a spatially explicit way.
- Provide a framework for rigorous scientific testing and implementation of locally relevant rehabilitative soil management interventions, addressing what works, what doesn't, where, how, and at what cost to individuals and society.
- Anticipate and respond to external requests from a wide audience (i.e., farmers, conservationists, scientists, and policy makers).

### *Presentation of Innovation-Diagnostic Surveillance and Operational Framework*

Human health surveillance techniques are a normal part of public health. Health surveillance is based on case definitions that define prevalence (percentage of people affected) and incidence (new cases). We propose an analogous land health surveillance system that provides the scientific and factual database essential to informed decision making and appropriate policy action (Shepherd and Walsh 2007).

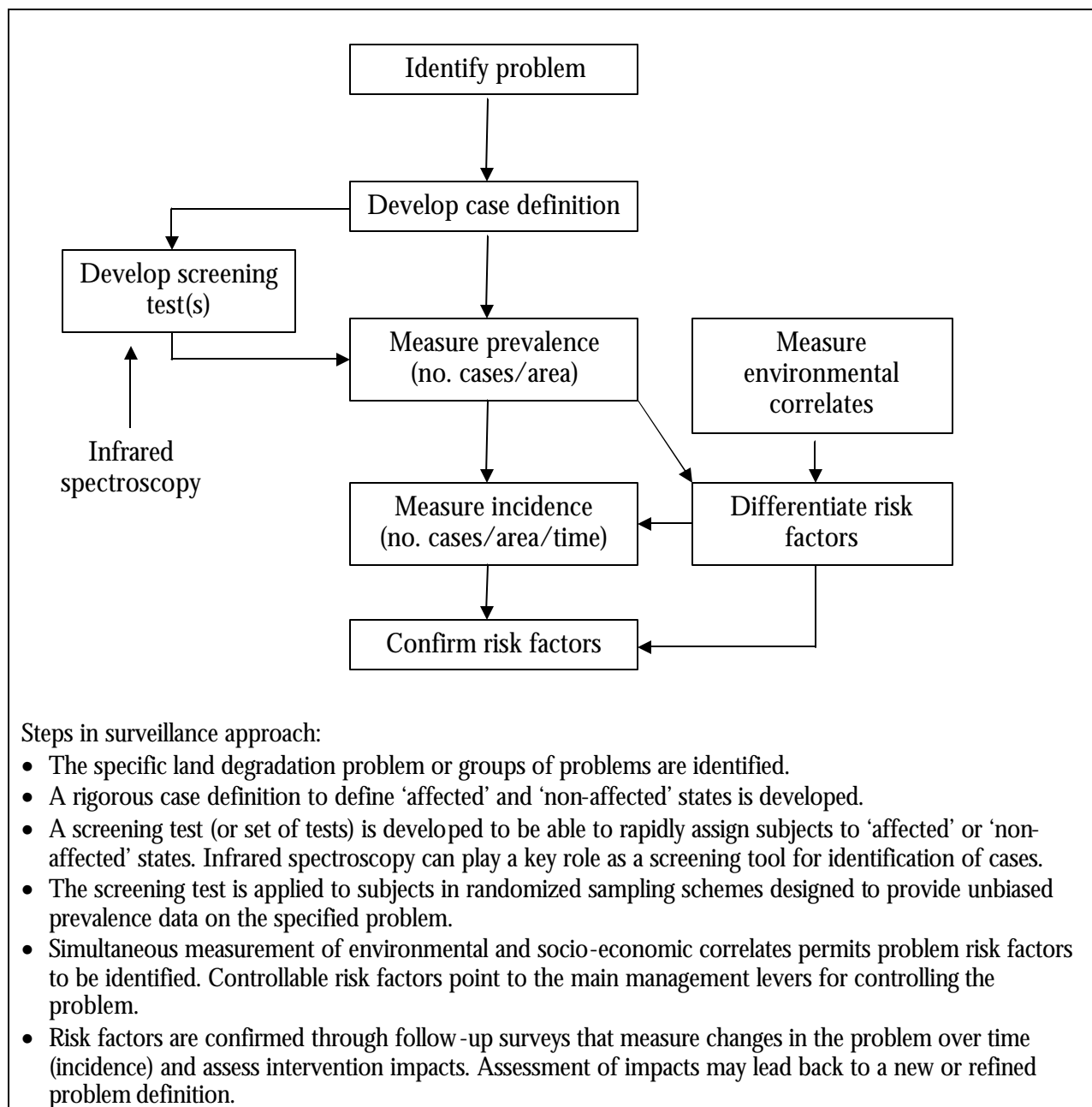
Soil health diagnostic surveillance aims:

- Provide diagnostic information on land degradation problems to guide resource allocation and management decisions.
- Identify cause-and-effect relationships needed for primary prevention, early detection, and rehabilitation of degraded land at different spatial scales.
- Provide a scientifically rigorous platform for testing and monitoring land management interventions.
- Provide a conceptual and logical framework for understanding coupled social-ecological systems.

A diagnostic surveillance framework (box 3.4) can provide a basis for a quantitative, evidence-based approach to land management. Having identified a problem, a critical step is to define a case definition through which the problem can be quantified. Problems such as disease in populations

generally exist as a continuum of severity, however for practical reasons it is often helpful to dichotomize the diagnostic continuum into “cases” and “non-cases” or “affected” and “non-affected.” The lack of rigorous stipulation of diagnostic criteria for key land degradation problems is a major impediment to the formulation of sound development policy. An adequate definition of what constitutes “degraded” or “non-degraded” land is a prerequisite to be able to assess the extent of land degradation.

### Box 3.4. Diagnostic Surveillance Framework



Source: ICRAF

Once case definitions are stipulated, a screening test is required to measure the problem in individuals or sample units and assign them as “case” or “non-case.” The availability of rapid,

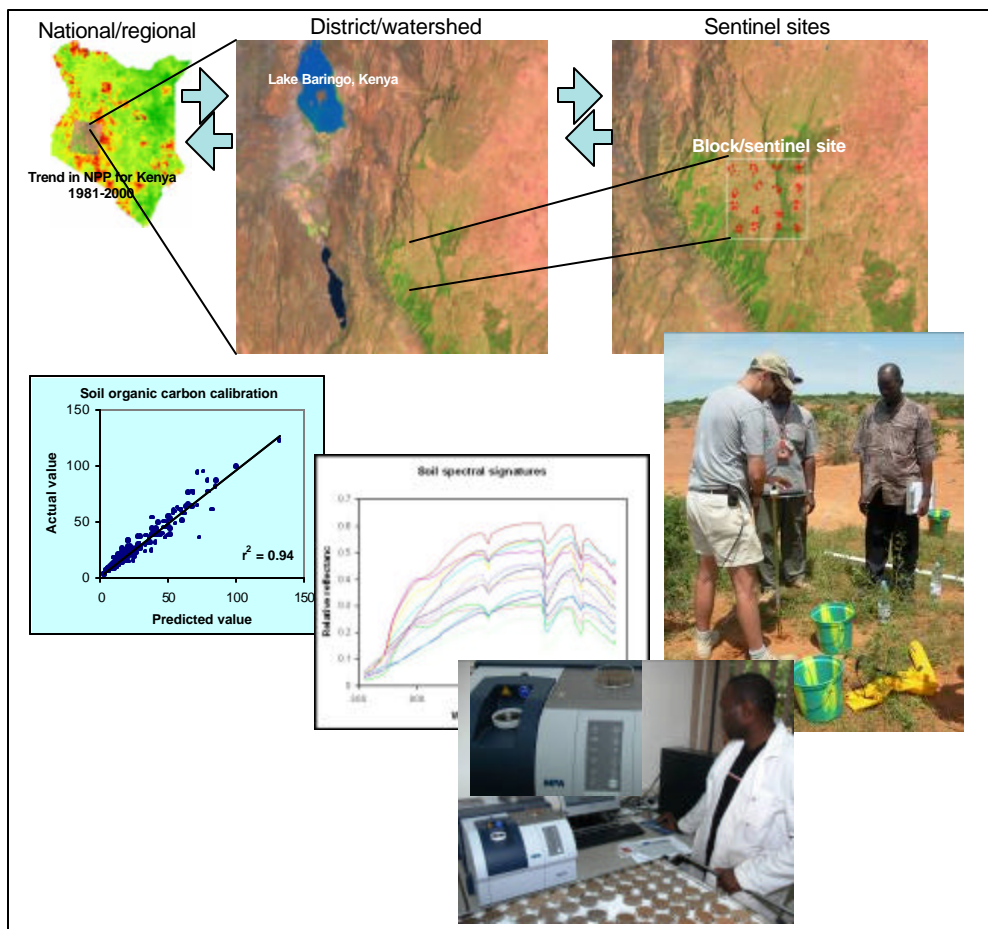
reliable (i.e., highly repeatable and reproducible) and cost-effective screening tests (e.g., equivalent to blood tests used in medicine), is key to making the surveillance framework operational in terms of being able to conduct prevalence surveys involving measurement on a large number of sample units. In clinical medicine large investments are made in development of screening tests, and even the case definition may be defined in relation to the screening test. For example, for some disorders an operational case definition is used where an arbitrary cut-off value of the screening test is used as a decision threshold for treatment.

The surveillance approach is operationalized using a combination of cutting edge tools (box 3.5) including: satellite remote sensing at multiple scales; georeferenced ground sampling schemes based on sentinel sites; infrared spectroscopy for rapid, reliable soil and plant tissue analysis; and mixed effects statistical models to provide population-based estimates from hierarchical data. The methods provide accurate information on where land degradation is taking place, the different manifestations of land degradation and soil constraints, the extent of the problems, and on what sort of intervention strategies are required to prevent or reverse degradation. The methods have been designed to be simple and cost-effective so that they can be implemented in isolated areas and in countries with limited resources.

At regional or national scale, land degradation risk domains are first established using low-resolution time-series satellite information on vegetation cover. These domains are further sampled using sentinel sites, consisting of 10-by-10-km blocks. Within sentinel sites, high-resolution imagery and ground sampling are used to gather data on vegetation and soil condition at randomized points. Infrared spectroscopy is used for rapid, reliable, and low-cost soil analysis and development of soil condition indices. Degradation indices are related to risk factors such as vegetation type and cover, and then mapped out through calibration to the satellite imagery using statistical inference. This information is used to spatially target land management strategies for systematic testing. The sentinel sites provide a framework not only for change detection through follow-up surveys (e.g., after five years) but also as a spatial platform for testing recommended land management options. For example, spatially distributing tree planting trials in each sub-block ensures that species are tested over a wide range of land conditions; consequently growth performance can be related back to site indices, which can be used to predict tree performance at new sites. The steps used in the framework are described in more detail in box 3.6.

The land degradation surveillance framework is being used in a UNEP capacity-building project to guide strategies for land restoration in five West African dryland countries (<http://www.worldagroforestry.org/wadrylands/index.html>) and in a World Bank-GEF project in Kenya, led by the Kenya Agricultural Research Institute, which is designed to tackle land degradation problems in the Lake Victoria basin. Soil health surveillance has been recommended as part of a NEPAD-endorsed strategy for saving Africa's soils (Swift and Shepherd 2007) and is proposed for Sub-Saharan Africa as a component of the Global Digital Soil Map of the World project (<http://www.globalsoilmap.net/>). Further information on infrared spectroscopy for sensing soil quality is available at: <http://www.worldagroforestrycentre.org/sensingsoil/>.

**Box 3.5. Land Degradation Problem Domains are Successively Sampled at a Hierarchy of Scales Using Satellite Imagery, Ground Sampling, and Laboratory Analysis of Soils Using Infrared Spectroscopy.**



Source: ICRAF

<b>Box 3.6 Steps in the Land Degradation Surveillance Framework</b>	
1.	At regional or national scale, land degradation risk domains are first established using low resolution time-series satellite information on vegetation cover in combination with long-term rainfall records. The risk domains indicate areas where land may have been degraded or recovered over the past 25 years and is used as a sampling frame for more detailed studies. Alternatively, stratification and sampling of the Landsat World Reference System grid can be used as a sampling frame. Ancillary data on population, infrastructure, climatic zones, etc. is integrated to build quantitative scenario analyses.
2.	Contrasting areas are then sampled using moderate-resolution (e.g., Landsat, ASTER, SPOT) satellite imagery, which provide data on major land cover conversions. Processing of full coverage imagery at this scale also provides data on prevalence of woody cover and bare soil areas. Variation within these areas is further sampled through Sentinel Sites to provide more detailed information on land condition. Sentinel Sites consist of 10-by-10 km blocks, which are logistically convenient for field sampling while being large enough to encompass major landscape variability.
3.	For the Sentinel Sites high-resolution (0.6-2.4 m) satellite imagery is obtained, which allows individual fields, trees, and erosion features to be observed. Within the sites a standardized, georeferenced ground survey is used to provide direct measurement of land condition. The 10-by-10 km blocks are spatially stratified into 2.5 km sub-blocks. Within each sub-block an area of 1-km <sup>2</sup> is sampled using a duster of 10 randomized 1000 m <sup>2</sup> observation plots. Direct observations are made in four 100 m <sup>2</sup> sub-plots. Socio-economic surveys also use the cluster design (e.g., sampling of households or villages nearest to cluster centroids).
4.	Within plots, observations are made on landform, topography, visible signs of soil erosion, land use, and vegetation type and cover, vegetation density and distribution, and soil samples are taken. Vegetation type is classified using the FAO Land Cover Classification System (LCCS), supplemented with woody biomass estimates. Single-ring infiltration measurements are made on a selection of plots (three in each cluster). A field crew of four people can complete a block in about 14-16 field days. The number of plots can be adjusted if desired to meet different objectives.
5.	Soil samples are characterized using infrared spectroscopy. This is a technique widely used in industry for rapid and routine characterization of materials, which has been adapted for rapid, reliable, and low- cost soil analysis. This no-chemical method is attractive for developing country laboratories because it minimizes sample preparation and only requires a source of electricity; furthermore, many agricultural inputs and products can be analyzed using the same instrument. Subsets of samples are sent to specialized laboratories for conventional soil analysis and isotope analysis. These expensive analyses, conducted on relatively few samples, are calibrated to the infrared spectral data and predicted for all samples. Also spectral indicators of soil condition are derived that successfully screen soils into intact or degraded categories.
6.	Standard data entry sheets are provided that can be enabled for web-based data entry. The data are compiled in a central database. Individual users are provided with a password access to their own data.
7.	Specialized statistical analysis for handling hierarchical data are used to derive population-based estimates for indicators of land condition and analyse the effect of environmental covariates (e.g., vegetation cover, soil spectral indicators) at different spatial scales. Development of robust statistical inference mechanisms with spatial models, pedotransfer functions, and expert systems are under development.
8.	The georeferenced sampling scheme allows ground observations (e.g., soil condition index) to be calibrated directly to satellite imagery and spatially interpolated and mapped.
9.	Electronic atlases are produced showing areas that are already degraded, areas at risk, and intact area; with matched recommendations on intervention strategies.
10.	Spatially explicit land management strategies are proposed for systematic testing. For example, enrichment planting of trees to meet specific tree density targets.
11.	The Sentinel Sites provide a framework not only for change detection through follow-up surveys (e.g., after five years) and as a spatial platform for testing land management interventions. For example, spatially distributing tree planting trials in the blocks ensures that species are tested over a wide range of land conditions, so that growth performance can be related back to site indices, which can be used to predict tree performance at new sites.

Source: ICRAF

### *Benefits and Impact of Activity*

The framework provides a scientifically rigorous framework for evidenced-based management of land resources, modeled on well-tested scientific approaches used in epidemiology. Currently there is no comparable system in operation. The systematic application of the approach will provide unbiased prevalence data on land degradation problems and permit quantification of land degradation risk factors, thereby enabling preventative and rehabilitation measures for sustainable land management to be appropriately targeted. The approach provides a spatial framework for testing interventions in landscapes in a way that samples the variability in conditions, thereby increasing the ability to generalize from outcomes. The baseline that the protocol generates provides a scientifically rigorous platform for monitoring impacts of intervention projects at a landscape level. The hierarchical sampling frame and statistical methods used allow for systematic aggregation of results and population level inferences to be made about land properties at different scales. The approach is particularly well-suited to providing high-quality information at low cost in areas such as Sub-Saharan Africa, where existing data on land resources is sparse.

The land degradation surveillance framework is being used in a UNEP capacity-building project to guide strategies for land restoration in five West African dryland countries and in a World Bank-GEF project in Kenya, led by the Kenya Agricultural Research Institute, which is designed to tackle land degradation problems in the Lake Victoria basin. Soil health surveillance has been recommended as part of a NEPAD-endorsed strategy for saving Africa's soils (Swift and Shepherd 2007) and is proposed for Sub-Saharan Africa as a component of the Global Digital Soil Map of the World project.

### *Lessons Learned and Issues for Wider Application*

The most difficult area for adoption is the advanced data analysis techniques used. An efficient solution to this barrier could be establishment of regional analytical centers, which would provide sampling schemes (global positions system points, standardized forms, and protocols), as well as remote sensing information and processing of field data posted by field teams via the web. In addition, the centers would fulfill a technical and scientific capacity building and support role.

### *Investment Needs and Priorities*

Widespread application of this approach principally requires investment in capacity building of national teams in the approaches and methods. Operational funds for implementing a national surveillance system in the field are modest and existing soil or natural resource survey departments could easily take up this role. The most difficult area for adoption is the advanced data analysis techniques used. An efficient solution to this barrier could be establishment of regional analytical centers, which would provide sampling schemes (global positions system points, standardized forms and protocols), remote sensing information, and processing of field data posted by field teams via the web. The centers would also fulfill and a technical and scientific capacity building and support role. Steps that a Government would need to take to implement a national level surveillance program:

1. Provide exposure training in the approaches and methods to a national team of scientists.
2. Equip a national soil laboratory with a near-infrared spectrometer (about \$75,000), provide basic training, ensure basic facilities for soil processing and storage, and limited conventional soil analysis.

3. Resource two survey teams for about 12 months of field work every five years (each team requires one surveyor, two field assistants, vehicle, GPS, auger set, and field operational funds) to establish sentinel sites (e.g., 50 sites) throughout the country.
4. Train up a national remote sensing/GIS lab in data analytical techniques with support from the above regional surveillance center.
5. Orient national agronomic testing and socioeconomic research programs to work through the sentinel sites. Establish additional sentinel sites for establishing baselines and monitoring outcomes for individual development projects aimed at land improvement.

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### **Web Resources**

<http://www.worldagroforestry.org/wadrylands/index.html>

<http://www.globalsoilmap.net/>

<http://www.worldagroforestrycentre.org/sensingsoil/>

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## **Investment Note: Adaptation and Mitigation Strategies in Sustainable Land Management Approaches to Combat the Impacts of Climate Change**

### *Summary*

Climate change has the potential to undermine significantly efforts in the sustainable management of agricultural land, particularly in subtropical and tropical regions. The impacts of climate change of concern to agricultural land management include amplification of drought/flood cycles, increase in wind and rain intensity, shift in the spatial and temporal distribution of rainfall, and range expansion of agricultural pests and diseases. The degree of this 'maladaptation' to climate variability could increase over the next several decades with climate change, potentially derailing future development efforts in climate vulnerable regions such as Africa.

Developing more coherent linkages between land management and institutional change could create a more conducive environment for land improvement. For example, the recent revegetation phenomena in the Sahel is rooted both in technical support for land improvement, as well as in legal code reforms that provided local communities with control over resource management decisions.

In Africa, with its dependence on rainfed agriculture the combined factors of variable rainfall, high temperatures, and poor soil fertility heighten the sensitivity of small-holder producers to shocks from extreme climate events. In the near to medium-term, there is reasonably good potential to enhance rainfed production sustainably through improvements in water capture and storage, combined with better soil and fertility management. There is potential from fairly modest changes to triple cereal yields in high-risk farming environments.

There are also opportunities to link green house gas (GHG) mitigation simultaneously with sustainable land use and adaptation to climate change. Other options include advances in probabilistic forecasting, embedding crop models within climate models, enhanced use of remote sensing, and research into 'weather within climate'. However, these advances will need to be matched with better means for disseminating forecasts to farming communities through multiple fora, such as where information on water, health, housing and disaster management is shared.

### *Introduction*

Climate change has the potential to significantly undermine efforts to sustain and manage agricultural land, particularly in subtropical and tropical regions. The impacts of climate change are of concern to agricultural land management. These impacts include: (a) amplification of drought/flood cycles, (b) increase in wind and rain intensity, (c) shift in the spatial and temporal distribution of rainfall, and (d) range expansion of agricultural pests and diseases (IPCC 2007). The disruptive impacts of climate change on agriculture are more likely to be experienced more in terms of increased seasonal and inter-annual climate variability, and a higher frequency of extreme events than as mean changes in climate.

These impacts will not be uniformly distributed nor will they be exclusively negative. High latitude zones that do not limit moisture are expected to experience increased productivity from warmer temperatures and longer growing seasons, assuming relatively modest temperature increases (< 3° C). On the other hand, low latitude zones that will undergo the smallest increase in warming will



likely be subjected to the greatest negative influence from climate change and variability because of the multiple pressures of land degradation, poverty, and weak institutional capacity. This combination of stress factors increases the vulnerability of small-holder producers to shocks from extreme climatic events, such as El Niño episodes, leading to a heightened risk of a poverty trap at the local level, and diminished economic growth at the national level (Brown and Lall 2006). The degree of this “mal-adaptation” to climate variability could increase over the next several decades with climate change potentially derailing future development efforts in climate vulnerable regions such as Africa.

Climate change has the potential to directly intersect with sustainable land management efforts by having an impact on soil function, watershed hydrology, and vegetation patterns; and indirectly through stimulating changes in land use practices, and altering the dynamics of invasive species. This module examines critical issues related to how climate change will impact soil and water management, and explores the potential to improve land management through efforts to mitigate agricultural greenhouse gas emissions, use seasonal climate forecasts to support agriculture management decisions, and adapt to climate variability and change.

#### *Key Sustainable Land Management Issues: Soil and Water Management*

Intensification of the hydrologic cycle with climate change manifested through increased frequency and intensity of flooding and drought, and more extreme storms with high-intensity rainfall, could significantly impact land management. Substantial increases in future soil erosion are projected, because of the important role of extreme events that contribute to total soil erosion (Nearing et al. 2004). Agricultural soils of the tropics are particularly vulnerable to erosion from extreme events because low soil organic matter levels and weak structure reduce their resilience to erosive forces; and crop productivity in these areas is quite sensitive to cumulative soil loss. Socioeconomic factors that mediate land use practices will also influence future changes in soil erosion risk. These would include shifts in cropping patterns and land use in response to market signals that would occur, for instance, with increased demand for bio-fuels, and rural outmigration.

Addressing the threat of increased soil erosion posed by climate change will require better quantification of the problem, greater attention to prioritizing which production systems and regions are vulnerable, and a redoubling of soil erosion management efforts.

- *Quantification:* Future approaches to soil erosion modeling and assessment will need to better capture the role of extreme events in soil erosion (Boardman 2006). Efforts to integrate meteorological time series from global climate models into soil erosion models are beginning to address this research gap. However, the complexity of these models will likely limit their use to wealthy regions. In developing regions, wider use of two-dimensional hillslope models and GIS can be employed to quantify erosion and develop landslide hazard maps.
- *Prioritization:* The fact that there will be limited resources for addressing the multitudinous impacts of climate change necessitates identification of priority areas where serious soil erosion is occurring and where these could accelerate with climate change. Boardman (2006) suggested identifying soil erosion ‘hotspots’ where anthropologically-induced soil erosion is high because of topography, climate, and population growth. These areas include (a) the Andes and Central American highlands, (b) Loess Plateau and Yangtze basin in China, and (c) in Africa, the countries of Lesotho, Swaziland, and Ethiopia and the Sahel.

- *Management:* Widening the adoption of practices and technologies that enhance soil coverage will become increasingly critical to future agricultural land management under climate change. The broad category of conservation agriculture contains many such interventions such as cover crops, agro-forestry, and improved fallows to reduce the period during which soil surfaces are exposed; which along with conservation tillage and use of green manuring can also maintain or increase soil organic matter levels and conserve soil moisture (Lal 2005; Sanchez 2000).

The resilience of conservation farming systems in the Central American highlands to El Niño drought, and the catastrophic soil losses from Hurricane Mitch provide strong evidence of conservation agriculture's soil stabilization potential. However, achieving broad-scale adoption of this set of practices is a significant challenge, given that factors such as land tenure instability, rural labor shortages, and non-farm income sources tend to have a dissuasive influence on soil improvement measures (Knowler 2004).

Developing more coherent linkages between land management and institutional change could create a more conducive environment for land improvement. For example, the recent re-vegetation phenomena in the Sahel is rooted both in technical support for land improvement as well as in legal code reforms that provided local communities with control over resource management decisions, such as in Niger where ownership of trees was transferred from central to local control. This policy change appears to have been an important catalyst for investments in agro-forestry and land rehabilitation. The area that has undergone re-vegetation is extensive, with estimates of between 2 and 3 million ha in Niger (US Geologic Survey unpublished), and 0.5 million ha in Burkina Faso (Reij et al. 2005).

Regions that are highly dependent on climate sensitive sectors are vulnerable to changes in water availability with climate change. Africa's dependence on rain-fed agriculture exemplifies this situation because of the combined factors of variable rainfall, high temperatures, and poor soil fertility heightens the sensitivity of small-holder producers to shocks from extreme climate events. A recent assessment by the Intergovernmental Panel on Climate Change (IPCC 2007) estimated that between 75 and 250 million people in Africa will experience increased water stress by end of this century, as a result of elevated surface temperatures, increased rainfall variability, and aridity. Semi-arid regions are the most vulnerable to rainfall reductions. For example, a 10 percent decrease in precipitation in regions receiving 500 mm/year is estimated to reduce surface drainage by 50 percent (de Wit and Stankiewicz 2006).

Long-term changes in precipitation patterns may simply reduce the total amount of land available for agriculture. However, in the near to medium-term there is reasonably good potential to sustain and enhance rain-fed production through improvements in water capture and storage combined with better soil management. One of the key challenges will be to diminish the feedback between water management risk and declining soil fertility, wherein the prospect of crop failure from insufficient soil moisture hinders investments in soil fertility, which in turn diminishes the potential of soils to capture and retain water; therefore, increasing the vulnerability to drought. One way to address this issue is focus on the "manageable part of climatic variability" through linking better in-situ rainfall retention with incremental amounts of fertilizer to bridge ephemeral dry spells that occur during sensitive plant growth stages. Rockström (2004) reported that these types of fairly small-scale changes can double and triple cereal yields in high-risk farming environments.

## *Lessons Learned*

Greenhouse gas (GHG) emissions from agriculture represent a significant source of climate forcing. Globally, agriculture contributes between 70 and 90 percent of anthropogenic nitrous oxide, between 40 and 50 percent of anthropogenic methane, and 15 percent of anthropogenic carbon dioxide emissions (DeAngelo et al. 2005). Land clearance for agriculture, nitrogenous fertilizer, flooded rice production, and livestock constitute the main sources of agricultural greenhouse gases.

Reducing the global warming potential of agriculture provides a number of opportunities to simultaneously link GHG mitigation with sustainable land use and adaptation to climate change. From a GHG mitigative standpoint, avoiding agriculturally-based emissions of  $\text{N}_2\text{O}$  and  $\text{CH}_4$  through enhanced factor productivity and energy efficiency is more economical than modifying land-use practices to enhance C sequestration in soil (Smith et al. 2007). Soil carbon sequestration, as a mitigative strategy, is less robust because C storage in soils is impermanent (i.e., lasting decades), is sensitive to management changes, and can result in elevated  $\text{N}_2\text{O}$  emissions.

## *Opportunities for Sustainable Land Management*

Specific options for linking GHG mitigation with sustainable land management include:

- *Change water management practices in paddy rice production:* Significant future reductions in  $\text{CH}_4$  emissions from rice can be achieved through improved water management. For instance, over the last two decades 80 percent of paddy rice production in China has shifted from continuously flooding to ephemeral drainage at mid-season. This resulted in an average 40 percent reduction in  $\text{CH}_4$  emissions and an overall improvement of yield because of better root growth and fewer unproductive panicles (Li et al. 2006). An additional 20 to 60 percent reduction in  $\text{CH}_4$  production is possible without sacrificing yield through adoption of shallow flooding and through slowing  $\text{CH}_4$  production by substituting urea for ammonium sulfate fertilizer (DeAngelo et al. 2005; Li et al. 2006).
- *Improve nitrogen use efficiency:* Reductions in  $\text{CH}_4$  emissions from rice do not necessarily lead to an overall reduction in net GHG emissions, as shifts between anoxic and oxic soil environments accelerate nitrification/denitrification processes resulting in greater  $\text{N}_2\text{O}$  production (DeAngelo et al. 2005; Li et al. 2006). Leakage of nitrogen from rice and other cropping systems can be reduced by better matching fertilizer application with plant demand, (e.g., through the application of slow-release fertilizer N, split fertilizer application, and nitrification inhibitors). Enhanced nitrogen use efficiency can also be achieved through the practice of site-specific nutrient management, in which fertilizer N is only used for supplying that increment not provided by indigenous nutrient sources. This can both reduce  $\text{N}_2\text{O}$  emissions and improve the economics of production through enhanced factor productivity.
- *Retain more biomass on agricultural lands:* Carbon sequestration on agricultural lands can be enhanced through the deployment of sustainable land use practices such as agro-forestry, conservation tillage, use of rotations and cover crops, and rehabilitation of degraded lands. Increasing C sequestration in soils, although less effective at reducing global warming potential than that of avoided emissions, is essential for bolstering the long-term sustainable management of soil and water. Other C sequestration practices such as agro-forestry and

improved fallows also contain a number of ancillary benefits: (e.g., improves income and nutrition, and protects biodiversity).

### *Seasonal Climate Forecasts and Sustainable Land Management*

Agricultural productivity and economic growth strongly track seasonal and inter-annual rainfall variability in countries that rely heavily on rain-fed agriculture (Brown and Lall 2006). This relationship has important implications for sustainable land management in highly variable climate regimes because investments in land improvement and yield enhancing technologies are often stymied by uncertainty and risk around the timing, distribution, and quantity of rainfall. To the extent that climate change is manifested as increasing intra- and inter-annual climate variability, the influence of rainfall uncertainty in dampening investments in sustainable land management could become even greater.

Advances in improving the skill of seasonal climate forecasts, and in developing pathways for disseminating and applying that information will be required to address this critical information gap. Forecasts that are timely and locally relevant can aid decision making in that in good rainfall years, farmers and supporting institutions can invest in greater inputs to recover from or prepare for production downturns in poor rainfall years when risk avoidance strategies are prudent (Hansen et al. 2006). Progress in climate-based crop forecasting will depend on (a) continued advances in probabilistic forecasting and downscaling, (b) embedding crop models within climate models, and (c) enhanced use of remote sensing and research into “weather within climate.” However, for seasonal climate forecasts to be effective, advances in forecasting skills will need to be matched with better means for disseminating forecasts to farming communities through multiple fora, such as where information on water, health, housing, and disaster management is shared (Vogel and O’Brien 2006).

### *Recommendations for Practitioners*

Climate change is occurring within a background of larger global change with respect to population growth, urbanization, land and water use, and biodiversity. Thus, efforts to adapt to the impacts of climate change should do so in a manner that is consistent with these broader development issues. In this context, there are several opportunities to apply the products and services developed for SLM that will enhance adaptation to climate change in agriculture. These include:

- *Address mal-adaptation to current climate variability.* There is significant scope for enhancing climate risk management in vulnerable regions, such as in El Niño impacted areas of southern and eastern Africa. This can be accomplished through (a) broader use of water conservation in agriculture, (b) better understanding of and support for local coping strategies, (c) resolving production bottlenecks such as access to seed, (d) promoting changes in policies to give local communities greater stake in resource management decisions, and (e) providing access to seasonal climate information by local decision makers.
- *Invest in soil protection:* Conservation agriculture practices and measures that increase soil organic matter and reduce the time that soils are bare will become more important for enhancing the resilience of soils to greater erosive forces with climate change. Stabilizing the resource base and replenishing soil fertility through low cost and locally relevant means is an important precursor to more technologically intensive adaptation measures such as

expansion of irrigation and use of drought tolerant varieties (Sanchez 2005). This is an area where SLM has significant knowledge and operational presence.

- *Couple soil fertility improvements with soil water management*: In small-holder production systems, farmers tend to invest in soil fertility only after other production risks; especially those associated with access to water are lessened. Reducing water risk is more cost effective than attempting to address absolute water scarcity. There are several entry points through which SLM could assist in this process, such as (a) through targeting small investments in rainwater capture and storage for supplemental irrigation, (b) promoting practices that reduce runoff to bridge the gap between rains, and (c) linking fertility inputs to seasonal rainfall projections.

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#### Selected Readings:

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Lai, R., B. A. Stewart, N. Uphoff, and D. O. Hansen eds. 2005. *Climate Change and Global Food Security*, 808 p. New York: Taylor and Francis.

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Sivakumar, M., H. Das, and O. Brunini 2005. "Impacts of Present and Future Climate Variability and Change on Agriculture and Forestry in the Arid and Semiarid Tropics." *Climatic Change* 70: 31-72.

Tirpak, D., and M. Ward. 2005. *The Adaptation Landscape*, 8 p. Organization of Economic Cooperation and Development. COM/ENV/EPOC/IEA/SLT 12.

This Note was prepared by Jon Padgham, USAID.

## Section IV. Web-based Resources (Tools and Methods) for Sustainable Land Management

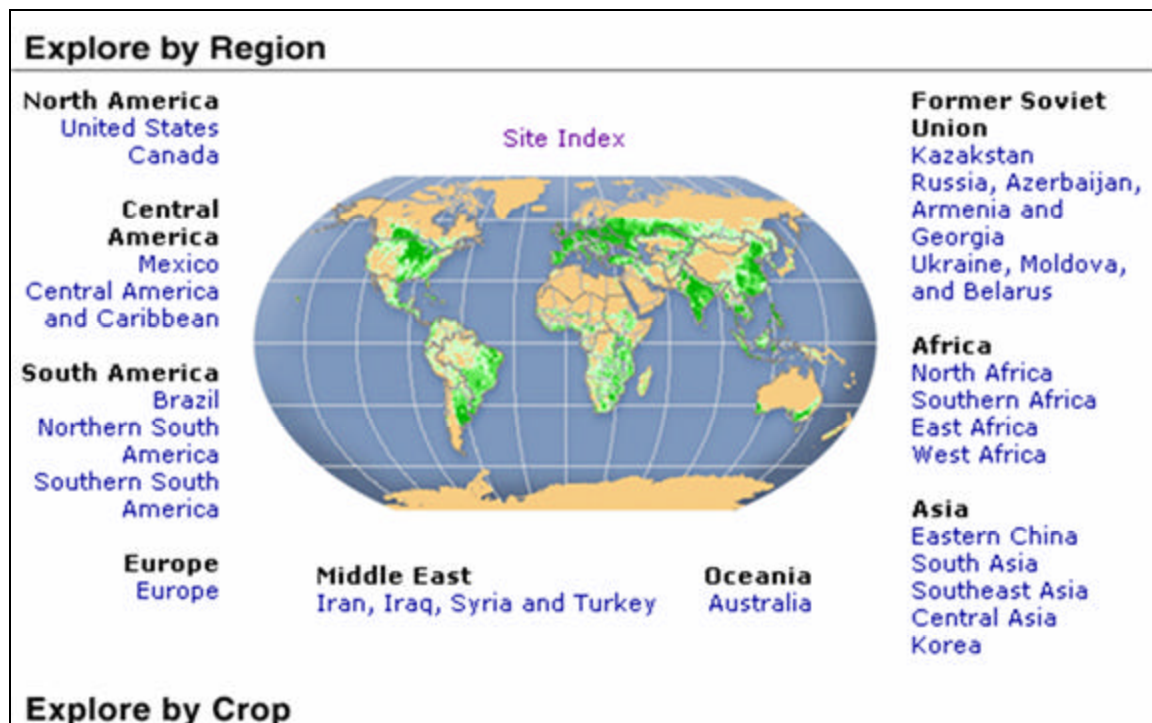
### *Overview*

This section provides direct links to key resources on tools and methods being developed by international, national, and civil society agencies that work on different aspects of land and natural resource management.

The links take users directly to the institutional pages of the agency responsible for the development of the tools and methods; and facilitate direct contact with the developers of the tools.

### *Global Field and Market Intelligence on Cereal and Oilseeds*

The USDA and Foreign Agriculture Service have a site where users can access near real time data and growing conditions for major cereal, fiber (e.g., cotton), and oilseed crops in most countries.



To use this tool click on: <http://www.pecad.fas.usda.gov/cropexplorer/index.cfm>



## [A Remote Sensing Tool for Water Resources Management](#)

The U.S. Department of Agriculture's Foreign Agricultural Service (USDA-FAS), in cooperation with the National Aeronautics and Space Administration, and the University of Maryland, are routinely monitoring lake and reservoir height variations for approximately 100 lakes located around the world. This project is the first of its kind to use near-real time radar altimeter data over inland water bodies in an operational manner.



Surface elevation products are produced by way of a semi-automated process, and placed at this web site for USDA and public viewing. Monitoring heights for ~100 reservoirs and lakes around the world will greatly assist the USDA/FAS/PECAD to quickly locate regional droughts, as well as improve crop production estimates for irrigated regions located downstream from lakes and reservoirs. All targeted lakes and reservoirs are located within major agricultural regions around the world. Reservoir and lake height variations may be viewed by placing the cursor on and clicking the continent of interest.

Link to global reservoirs:

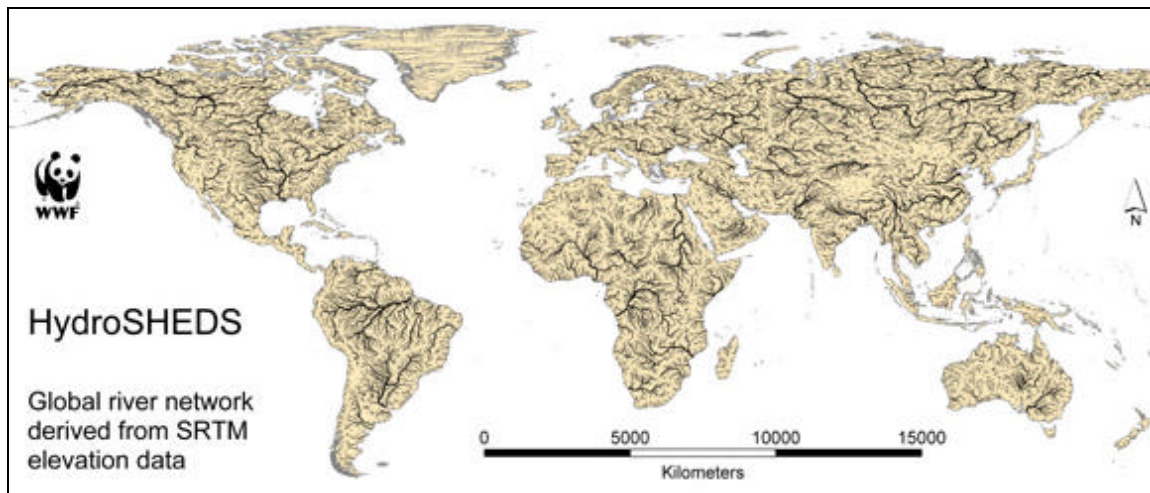
[http://www.pecad.fas.usda.gov/cropexplorer/global\\_reservoir/](http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/)



## Hydrological Data and Digital Watershed Maps

The World Wildlife Fund's Conservation Science Program is currently developing a new and innovative global hydrological database, called "HydroSHEDS." For many parts of the world these data, and the tools built to use them, open up a range of previously inaccessible analyses and applications related to freshwater conservation and environmental planning. HydroSHEDS is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM). HydroSHEDS stands for "Hydrological data and maps based on Shuttle Elevation Derivatives at Multiple Scales."

At the most basic level, HydroSHEDS allow scientists to create digital river and watershed maps. These maps can then be coupled with a variety of other geo-spatial datasets or applied in computer simulations, such as hydrologic models, in order to estimate flow regimes. HydroSHEDS allows scientists and managers to perform analyses that range from basic watershed delineation to sophisticated flow modeling.



HydroSHEDS can be used for a wide range of applications. WWF has already applied the data to create aquatic habitat classification maps for remote and poorly mapped regions such as the Amazon headwaters and the Guiana Shield. Taxonomists will ultimately be able to link their field site locations directly to digital river maps. And WWF researchers hope to use HydroSHEDS in the future to assess the possible impacts of climate change to freshwater ecosystems.

HydroSHEDS has been developed by the Conservation Science Program of World Wildlife Fund (WWF), in partnership with the U.S. Geological Survey (USGS), the International Centre for Tropical Agriculture (CIAT), The Nature Conservancy (TNC), and the Center for Environmental Systems Research (CESR), at the University of Kassel in Germany. Major funding for this project was provided to WWF by JohnsonDiversey, Inc.

Data for South America, Central America, and Asia are now available. Other continents are scheduled for completion within a year. HydroSHEDS data are freely available for non-commercial use.

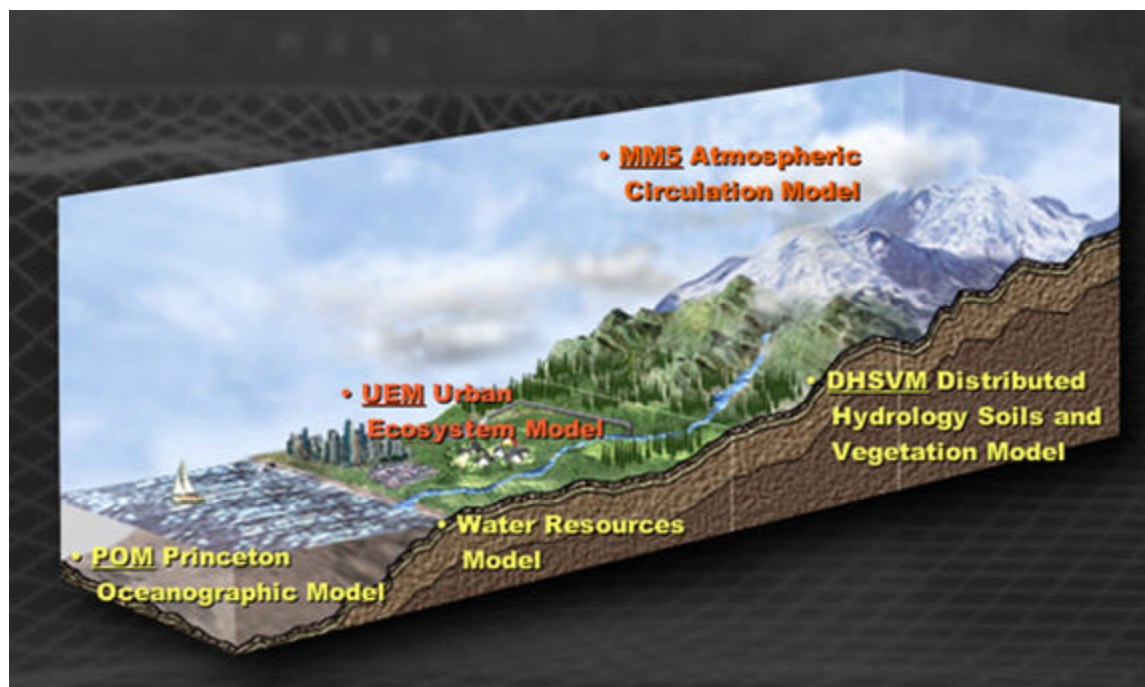
For more information and data download please visit: <http://hydrosheds.cr.usgs.gov>

## *Basin and Watershed Scale Hydrological Modeling*

The hydrology of a regional-scale river system can be modeled as a geospatially-explicit water mass balance for each grid cell within the basin contributing to stream flow and downstream routing. As such, a model can be divided into two major components: (a) a “vertical” component, that calculates the water balance at each individual grid cell, and (b) a “horizontal” component, that routes the runoff generated by each grid cell to the ocean. This split into two separate components has a number of advantages. It separates the “indirect water routing” and “direct water diversions.” The former, includes impacts of land use change and climate change and are expressed mainly through the “vertical” model; that is, the water balance at the grid cell level. The latter, includes increased withdrawals and diversions for agricultural, industrial, and domestic use; and has an impact mainly on the “horizontal” model which represents the flow routing. The separation into the grid cell and channel components allows for an easy interface to treat non-point source and in-channel chemical processes separately.

To learn more about VIC, click on the following link:

<http://www.hydro.washington.edu/Lettenmaier/Models/VIC/VIChome.html>



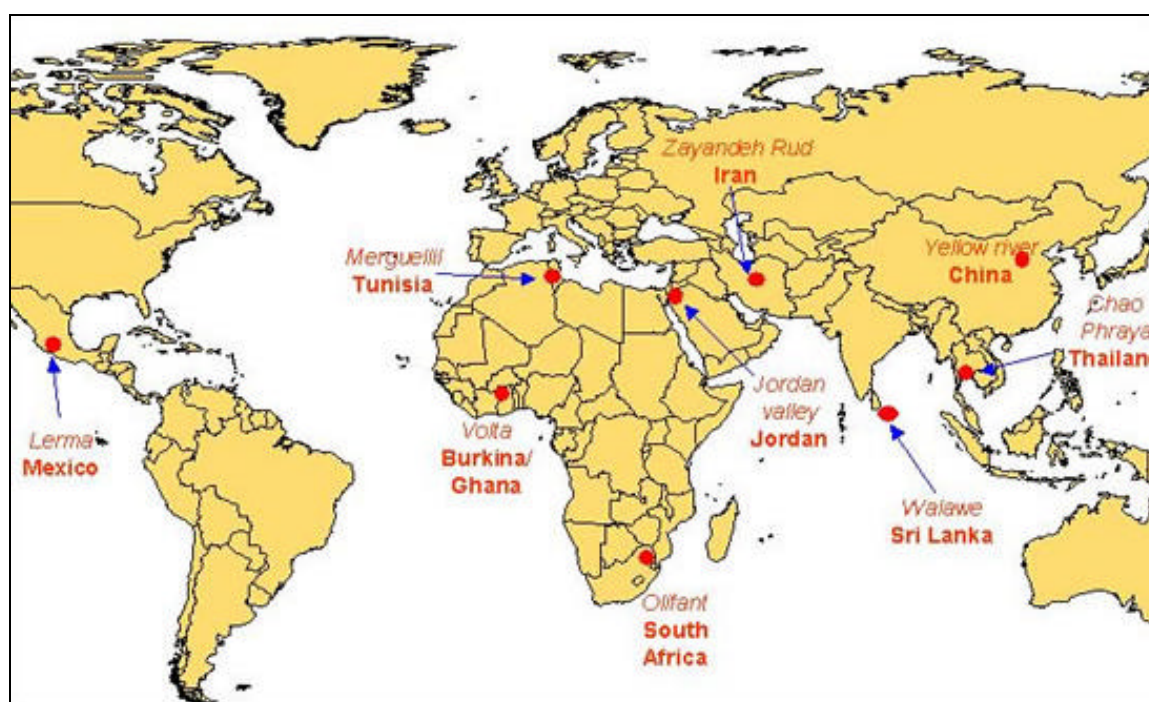
The Distributed Hydrology Soil Vegetation Model (DHSVM) is a distributed hydrologic model that explicitly represents the effects of topography and vegetation on water fluxes through the landscape. It is typically applied at high spatial resolutions on the order of 100 m for watersheds of up to  $10^4$  km<sup>2</sup> and at sub-daily timescales for multi-year simulations.

To learn more about DHSVM click on:

<http://www.hydro.washington.edu/Lettenmaier/Models/DHSVM/index.shtml>

## *River Basin Development and Management*

International Water Management Institute (IWMI) is documenting the historical development of nine river basins from different parts of the world to derive generic understanding on how societies manage water resources under growing population and basin closure, which problems are faced, and which range of solutions (technical, institutional) are available for a given physical and societal context. The studies first address the past transformations of each basin, periodize changes and draw lessons on how population growth and water resource development related to food production and environmental degradation and preservation. They investigate in more detail the present situation and define the scope for improvement in management, allocation, environmental services, and income generation. A third part deals with projections and scenarios, with the aim to inform current or future stakeholders' dialogues, and provide decision makers with a state-of-the-art analysis and understanding of the basin challenges and opportunities.



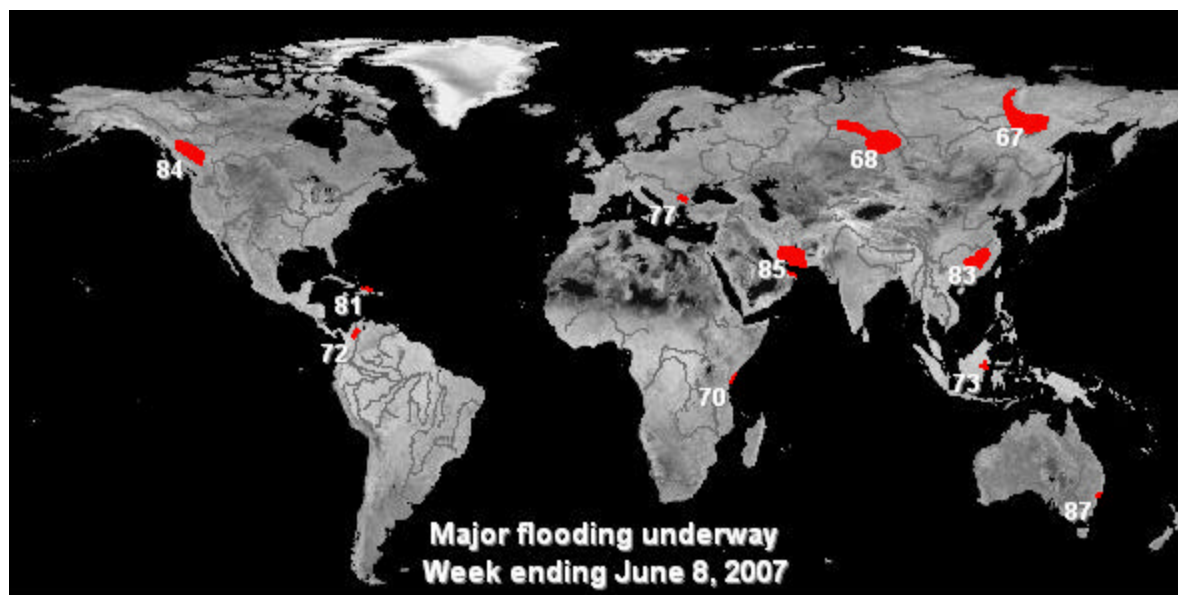
To learn more about the conceptual framework, basin studies and tools, click on:

[http://www.iwmi.cgiar.org/assessment/Research Projects/River Basin Development and Management/index.htm](http://www.iwmi.cgiar.org/assessment/Research%20Projects/River%20Basin%20Development%20and%20Management/index.htm)

*Tracking Floods Globally: The Dartmouth Flood Observatory*

The Observatory detects, maps, and measures major flood events world-wide using satellite remote sensing. The record of such events is preserved here as a World Atlas of Flooded Lands.

An Active Archive of Large Floods, 1985 to present, describes these events individually. Maps and images accompany many of the floods, and can be accessed by links in the yearly catalogs. As the archive of reliable data grows, it is increasingly possible to predict where and when major flooding will occur, and to analyze trends over time.



Surface Water Watch is a satellite-based surface water monitoring system. Orbital AMSR-E microwave measurements over selected river reaches and wetlands are used to measure discharge and watershed runoff. The system can be used to determine where flooding is underway today, to predict inundation extents, and to assess the current runoff status of watersheds. For rivers in cold regions, river ice status is also being monitored.

To access the Flood Observatory and products, please click on:  
<http://www.dartmouth.edu/~floods/index.html>

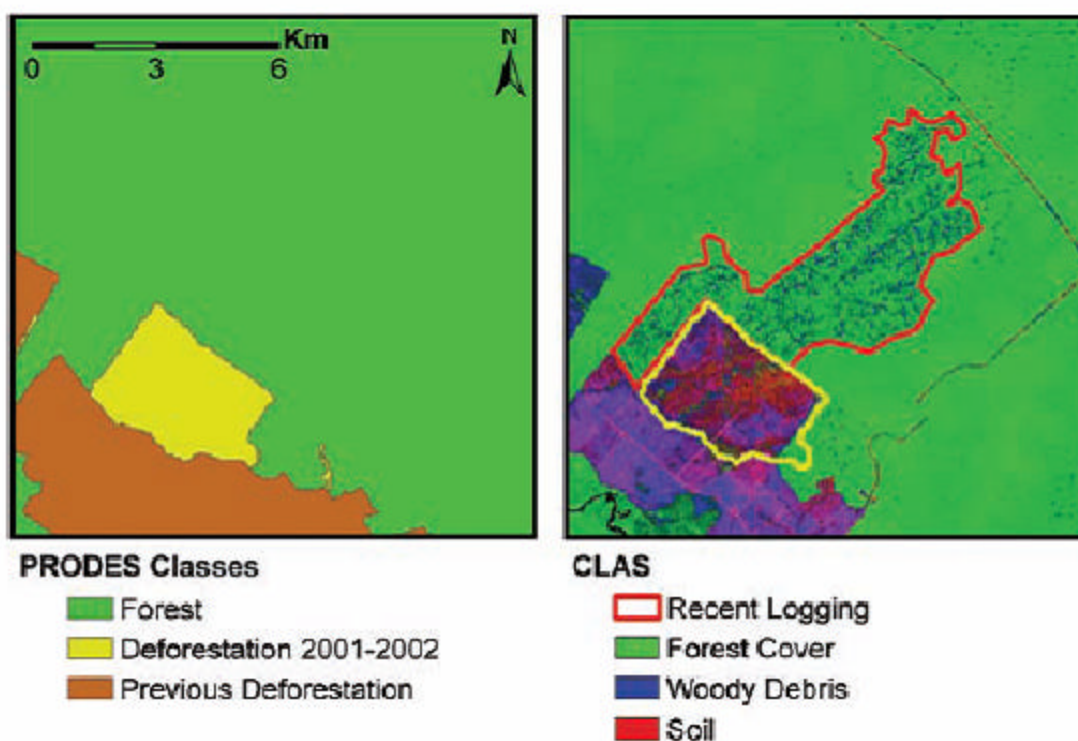


### *The Carnegie Landsat Analysis System (CLAS)*

Problems in detecting selective logging with remote sensing are linked to the fact that tree species diversity in some tropical rainforests (e.g., the Brazilian Amazon, the Congo) is very high, and most species are locally rare. Logging is highly selective because markets accept only a few species for timber use. This contrasts with logging practices in other parts of the world where clear-cutting or nearly complete harvests predominate. These large differences in logging intensity result in variation of forest disturbance and collateral damages caused by harvesting activities.

The Carnegie Landsat Analysis System (CLAS) uses high-spatial resolution satellite data for regional and global studies of forest disturbance. CLAS is an automated processing system that includes: (a) atmospheric correction of satellite data; (b) deconvolution of spectral signatures into sub-pixel fractional cover of live forest canopy, forest debris, and bare substrates; (c) cloud, water, and deforestation masking; and (d) pattern recognition algorithms for forest disturbance mapping.

An example of the CLAS High-resolution detection of selective-logging in the eastern Amazon during the period 2001–2002 from the CLAS processing (right), compared with deforestation mapping provided by standard Landsat processing (PRODES).



For more information on CLAS and associated publications click on:

[CLAS](#)

### *Plant Biodiversity – Rapid Survey, Classification, and Mapping*

The Center for Biodiversity Management (CBM) provides users worldwide with free access to state-of-the-art biodiversity assessment methodology and related software.

#### *VEGCLASS 2.0 – Field Tool for Vegetation Data Entry and Classification*

VegClass is a computer-assisted data-entry and analytical package for general vegetation classification and analysis. It is built around a novel system of classifying vegetation according to morphological adaptations to environment as well as species, vegetation structure, and the additional recording site physical features. The software allows the user to choose between a range of variables to suit a particular purpose and scale. References to the theory and practice underlying this software are available in scientific literature, as well as on the Internet. The software runs on PCs under Windows® with instructions in simple English. With minimal training it can be used as a powerful tool for both entering and compiling field data using a formal protocol that allows transfer of data summaries into a wide range of industrial computerized spreadsheet and relational database formats such as Excel® and Microsoft Access®.

Apart from being useful in the field, VegClass is an excellent tool for training purposes and has been successfully used in a number of developing countries (Tropical West Africa (Cameroon) and the Sub-Sahel (Mali), southern Africa (Mozambique), Indomalesia (India, Indonesia, Thailand, Vietnam, and the Philippines), and Latin America (Costa Rica, Brazil, Perú). Because it provides a ready means of producing standardized data sets, VegClass is rapidly becoming popular in vegetation surveys in different countries. It provides a unique, generic means of recording and comparing data within and between regions; and it is a unique tool for global and local comparative purposes. VegClass has been supported by the Center for International Forestry Research (CIFOR) as well as CBM.

#### *DOMAIN – Habitat Mapping Package*

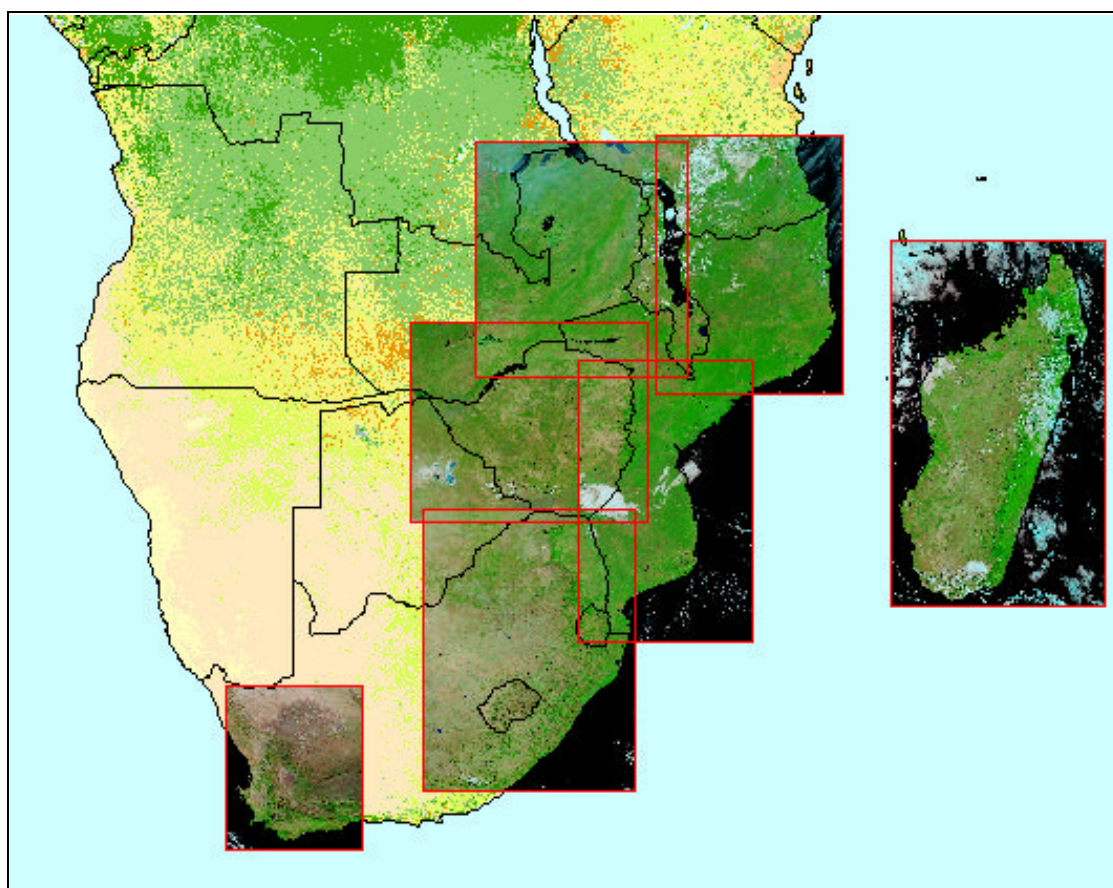
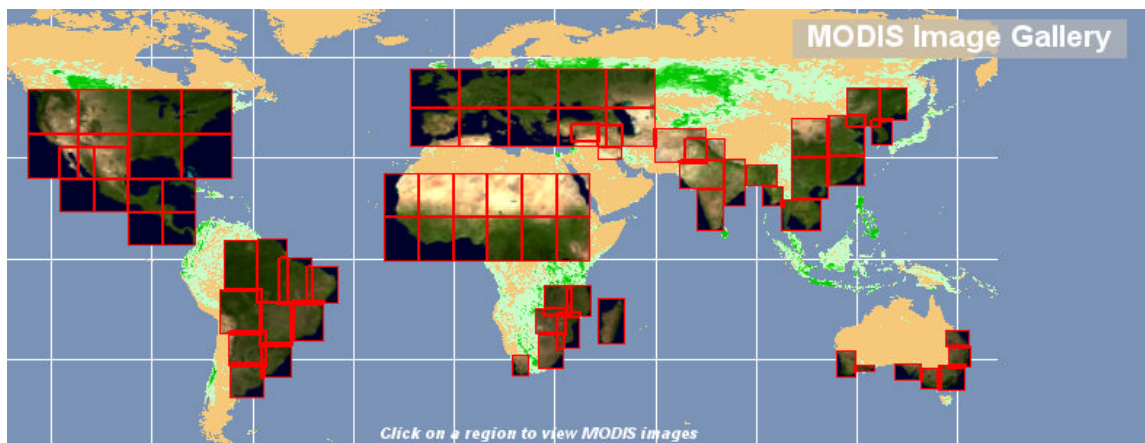
DOMAIN is a user-friendly software program that makes it possible to explore potential habitats for plant and animal species. Unlike many other potential mapping programs, DOMAIN allows the use of relatively few spatially-referenced data points such as known species locations. When these are overlaid on known environmental variables such as soil type, elevation, and certain climate variables, the program constructs an environmental DOMAIN map showing different levels of similarity. This program is now widely used in more than 80 countries.

To learn more and to access the free VegClass and DOMAIN software click on:

<http://www.cbmglobe.org/softwaredev.htm>

*Agricultural Production Regions and MODIS: NASA's - Moderate Resolution Imaging Spectroradiometer*

Mosaic images were created by the NASA MODIS Rapid Response System team to overlap the agricultural regions shown by the red rectangles below. New MODIS mosaics are produced daily for each agricultural region in false color and true color from the Terra and Aqua satellites at 1km, 500m, and 250m resolution. These near real-time images can be viewed and downloaded after clicking on a region outlined in red.

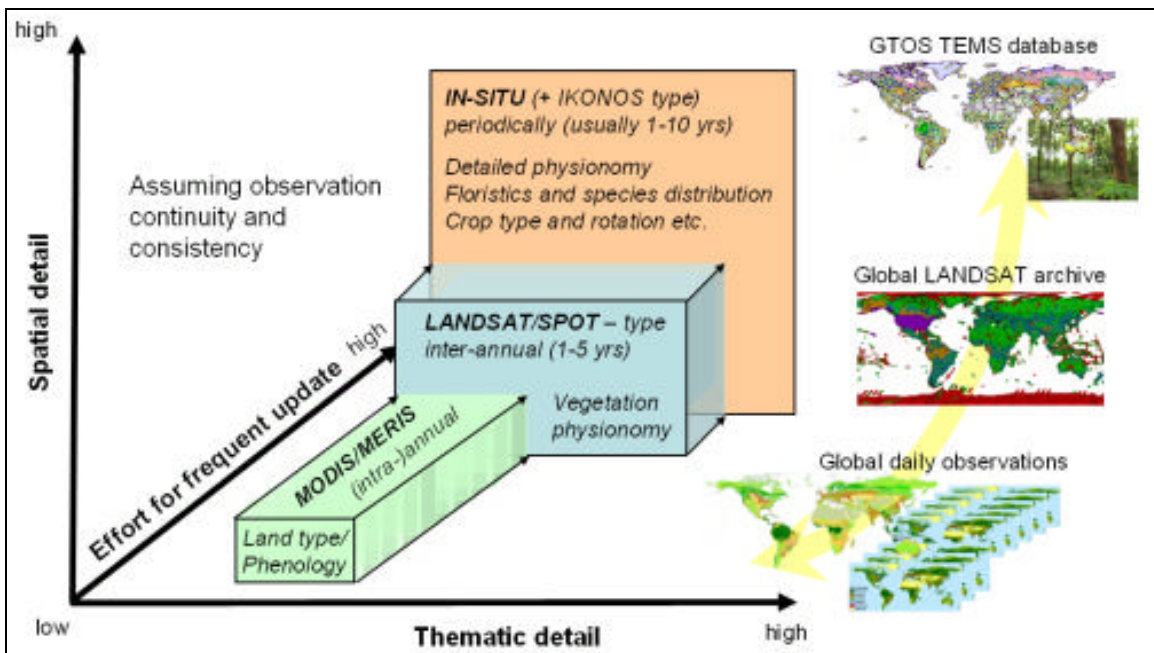


To access daily images click on: [MODIS Integrated Global Observations for Land \(IGOL\)](#)

Since its creation in 1998 the Integrated Global Observing Strategy (IGOS) seeks to provide a comprehensive framework to harmonize the common interests of the major space-based and in-situ systems for global observation of the earth (<http://www.eohandbook.com/igosp/>).

Integrated Global Observations for Land (IGOL) is the land theme of IGOS and has the responsibility to design a cohesive program of activities that will provide a comprehensive picture of the present state of terrestrial ecosystems, and build capacity for long-term monitoring of those ecosystems (<http://www.fao.org/gtos/igol/>). GOF-C-GOLD is strongly involved in developing the IGOL theme. The current IGOL aims at an integrated and operational land observing system focuses on the following areas:

- Land cover, land cover change, fire
- Land use, land use change
- Agricultural production, food security, sustainable agriculture and forestry
- Land degradation and soils
- Ecosystems, ecosystem goods and services
- Biodiversity and conservation
- Human health, impacts of land properties on vectors
- Water resource management, water use for agriculture, human use
- Disasters early warning systems disasters (fires, floods, and droughts),
- Climate change impacts on land properties
- Energy (biomass, fuelwood)
- Urbanization and infrastructure



For global observation of the earth: (<http://www.eohandbook.com/igosp/>)



## **GLOSSARY**

Many of the definitions in this glossary have been sourced from the Intergovernmental Panel on Climate Change at <http://www.ipcc.ch/pub/syrgloss.pdf>.

### **Abatement**

Processes and technologies leading to the reduction of greenhouse gas emissions.

### **Adaptation**

Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates, harms, or exploits beneficial opportunities.

### **Afforestation**

The act or process of establishing a forest where there has not been one in recent history.

### **Afforestation Grant Scheme (AGS)**

A scheme proposed by the Government whereby landowners would be invited to tender for grants for the establishment of new post-2007 Kyoto-compliant forests.

### **Agricultural Plains, Lowland Plains or Plains**

Refers to the lower part of river basins between the headwaters and the coastal areas (except in urban areas). They are mainly flat or rolling lands with large streams or rivers. In Asia and parts of Latin America, they typically contain large contiguous areas with rain-fed agriculture and irrigation systems. Huge areas are under low-intensity grazing or ranching in Latin America and Africa.

### **Agriculture**

All human activities where natural resources are used to produce the raw materials for food, feed, and fiber. Use of equipment, fertilizer and fossil energy in the process is common, and so is the use of irrigation water. Agriculture includes crop production, livestock production fisheries and timber. In most cases, the products are sold to markets.

### **Agro-ecological system**

The total of natural resources, people, and their interactions, in an area, where the processes within the system are relatively independent of those in other agroecological systems.

### **Annex I Countries**

Group of countries included in Annex I to the United Nations Framework Convention on Climate Change, includes all of the developed countries in the Organisation for Economic Cooperation and Development, and economies in transition (including Russia and Ukraine).

### **Annex B Countries/Parties**

Group of countries included in Annex B in the Kyoto Protocol that agreed to a target for their greenhouse gas emissions -- includes all the Annex I countries except Turkey and Belarus.

### **Biofuel**

A fuel produced from plants, animal products and waste. Biofuels include alcohols, biodiesel -- "black liquor" from the paper manufacturing process, wood, and soybean oil.

**Carbon credits**

A tradeable unit that represents the right to emit one ton of carbon dioxide-equivalent emissions.

**Carbon dioxide (CO<sub>2</sub>)**

A naturally occurring gas that is a by-product of burning and a breakdown of fossil fuels and biomass, land-use changes, and other industrial processes. It is the principal human-induced greenhouse gas that affects the earth's temperature.

**Carbon dioxide equivalent (CO<sub>2</sub>e)**

The quantity of a given greenhouse gas multiplied by its global warming potential (GWP), which equates its global warming impact relative to carbon dioxide (CO<sub>2</sub>). This is the standard unit for comparing the degree of warming which can be caused by emissions of different greenhouse gases.

**C (Carbon)-sequestration**

The process by which carbon (C) from the air (in CO<sub>2</sub>) is absorbed by growing plants and trees, and is left in dead plants (dead roots, exudates, mulch) in the soil. C sequestration increases soil organic matter. It counteracts buildup of CO<sub>2</sub> in the air and hence climatic change, and is also an aspect of land rehabilitation: the more C is retained in the soil, the better its fertility, water-holding capacity and resilience.

**Climate change**

A change in climate, attributed directly or indirectly to human activity, that alters the composition of the global atmosphere; and that is additional to natural climate variability observed over comparable time period.

**Coastal areas**

The land area between the coast of the sea or the ocean and a line approximately 100 km inland with all water bodies in it, plus the marine zone where most fisheries, aquaculture, and tourism take place.

**Co-benefits** The benefits of policies that are beyond the scope of the original policy.

**Commitment Period (CP)** A range of years within which Parties to the Kyoto Protocol are required to meet their greenhouse gas emissions target, which is averaged over the years of the commitment period. The first commitment period is 2008-2012. The targets are set relative to greenhouse gas emissions in the base year (in New Zealand's case, 1990), multiplied by five.

**Deforestation** The direct human-induced conversion of forested land to non-forested land (i.e., as agriculture).

**Degradation**

In this publication, *degradation* is defined as the sum of the processes that render land or water economically less valuable for agricultural production or for other ecosystem services.

Continued degradation leads to zero or negative economic agricultural productivity. Degraded land and water can have a significant nonagricultural value, such as in nature reservations, recreational areas, and for houses and roads, even though for these purposes non-degraded lands are far superior. "Soil" degradation refers to the processes that reduce the capacity of the soil to support agriculture. Comprised of different soil types combined in a particular landscape. Land use refers to

the type of management; major categories are annual crops, perennial crops, fallows, pastures, herding on rangelands.

### **Desertification**

Form of land degradation in which vegetation cannot re-establish itself after removal by harvesting, burning or grazing. It is because of overexploitation, and may occur in nearly every climate, but particularly in semi-arid environments. Strong winds increase the vulnerability to desertification.

### **Devegetation**

The removal of natural vegetation and crops that leave the surface bare and exposed to degradation by water, wind erosion, and leaching. Deforestation is the form of devegetation where trees and shrubs are removed. Reestablishment of plant and tree species in devegetated areas is often difficult because of harsh environmental conditions for germination and establishment. Grazing of emerging plants can modify the vegetation composition significantly so that mainly unpalatable, weedy species are present in low density, rendering land unfit for agriculture. Devegetation can lead to desertification.

### **Ecological footprint**

The virtual area cultivated or exploited to grow the crops and livestock, which supply the food that an average person consumes annually. Typically, this area is not contiguous, and part of this area may be far away, even in other countries. Its value ranges from 100 m<sup>2</sup> to 1 hectare, or even beyond these values, depending on the type of food consumed (vegetarian or rich in animal protein) and the productivity of the farming system (dependent on the intensity of management practices, and the quality of the natural resources). The size of the ecological footprint can be used to compare consequences of different lifestyles in different zones.

### **Ecosystem services**

Refers to various benefits that ecosystems provide to people that include food, clean water, nature, and wildlife; and protection against natural disasters such as flooding. Agriculture is always part of an ecosystem, and agriculture can be seen as an ecosystem service.

### **Emissions**

The intentional and unintentional release of greenhouse gases into the atmosphere.

**Emission unit or allowance** A tradeable unit representing the right to emit one ton of carbon dioxide-equivalent emissions.

### **Encroachment**

People use land for agriculture in protected natural areas. Although predominant in headwaters and coastal areas, it is also common in plains. The term refers to people moving on to new land, which happens when they have few alternatives for food production in unprotected areas. In other situations, people have been living in and cultivating the “encroached” area for a long time, albeit in smaller numbers, and the notion of protected area was recently imposed on them.

### **Environmental flow**

The flow of water required to maintain healthy wetlands and other ecosystems.

**Environmental security**

Refers to the condition of natural resources in a particular area. Full environmental security is achieved when the resources provide full environmental services to the human beings who depend on this area and when this condition is sustainable. Rehabilitation of degraded areas to achieve this situation is only feasible if the damage threshold has not been exceeded.

**Erosion**

Refers to the process of movement of soil particles, with organic matter and nutrients contained in them, because of rain, water movement or wind. Erosion is accompanied by deposition nearby or at a distance. Erosion is a natural process that can be accelerated by soil cultivation or deforestation. Construction of infrastructure (i.e., roads, paths) can contribute much toward accelerating erosion.

**Evapotranspiration**

Refers to the process by which water passes from the liquid state in soil and plants into a gaseous state in the air. Only the fraction that passes through plants can contribute to crop production.

**Food security**

In this report, this term indicates the production of food, the access to food and the utilization of food. For global food security, the emphasis is that sufficient food is produced in the world to meet the full requirements of all people: total global food supply equals the total global demand. For household food security, the focus is on the ability of households, urban and rural, to purchase or produce food they need for a healthy and active life; disposable income is a crucial issue. Women are typically gatekeepers of household food security. For national food security, the focus is on sufficient food for all people in a nation; it can be assured through any combination of national production and food imports and exports. Food security always has components of production, access and utilization.

**Forest**

A minimum area of one hectare of land with tree crown cover (or equivalent stocking level) of more than 30 percent; with trees able to reach the potential of a minimum height of 5 meters at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations that have yet to reach a crown density of 30 percent or tree height of five meters are included under this definition. So, too, are areas normally forming part of forest that are temporarily unstocked as a result of human interventions, such as harvesting or natural causes, but are expected to revert to forest.

**Fossil fuel**

A fuel that is sourced from fossilized biomass such as oil and gas.

**Greenhouse gas (GHG)**

Greenhouse gases are constituents of the atmosphere, both natural and human-induced, which absorb and re-emit infrared radiation. Greenhouse gas emissions covered by the emissions limitation commitment for the first commitment period of the Kyoto Protocol are carbon dioxide ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride ( $\text{SF}_6$ ).

**Greenhouse gas intensity/Global Warming Potential (GWP)**

This index approximates the time-integrated warming effect of a unit mass of a given greenhouse gas in today's atmosphere, relative to that of carbon dioxide.

**Gross domestic product (GDP)**

Represents the national income earned by production in a country.

**Hotspots**

Are the areas where the particular degradation problem is relatively intensive and significant.

**Intergovernmental Panel on Climate Change (IPCC)**

Established by the World Meteorological Organization and the United Nations Environment Program to assess scientific, technical, and socioeconomic information relevant for the understanding of climate change; and its potential impacts and options for adaptation and mitigation.

**Globalization** refers to the process by which more and more goods and services are traded internationally. It encompasses also greater commercialization of farming and more dependence on trade for achieving food security.

**Grain equivalent**

Our daily food has an endless variety of composition, water content, edible parts, and is produced from many crops. To express all in a single dimension, the term *grain equivalent* is used. It indicates by how much weight of grain (typically wheat) a certain amount of food could be replaced.

**Groundwater**

Water extracted from the soil depth beyond the rooting zone, generally with manual or motorized pumps.

**Groundwater depletion**

Process of extraction of groundwater from below the rooting zone, sometimes from depths below 50 m, at a rate faster than groundwater recharge takes place.

**Headwaters (or upland watersheds)**

Refers to the upper parts of river basins where water is collected in small streams that merge into larger ones, and often flow into a reservoir or major river. Headwaters are typically hilly and mountainous areas originally forested or covered with perennial vegetation; and in many cases the home of nature reservations. People in headwaters, sometimes living in tribes or other groupings of minorities, include the poorest people with often less formal rights than those downstream.

**Heterogeneity and diversity**

These terms refer to gradual changes in the nature and intensity of natural resources in space or in time, and to sociological and cultural diversity among the people living there. This natural phenomenon is the cause of problems and opportunities, but it makes effective management always highly site- and situation-specific. People at "peaks" can do very well. Poor people are generally found at the "troughs."

**Holistic and participatory approaches**

Successful approaches to reducing degradation and improving food security consider how to make the best use of, or to increase, all resources that people should have at their disposal: natural, human, physical, social and financial resources.

**Kyoto Protocol**

A protocol to the United Nations Framework Convention on Climate Change that requires ratifying countries listed in its Annex B (industrialized nations) to meet greenhouse gas reduction targets during the period from 2008 to 2012 (see <http://unfccc.int> for further information).

**Kyoto forest**

Forest that has been established by direct human activity on land that was not forest land as of December 31, 1989.

**Kyoto compliant land**

Land that was non-forest land as of December 31, 1989.

**Land managers**

Farmers (includes arable, horticultural, and pastoral) and foresters.

**Low-emissions technologies**

Technologies that lead to reduced emissions of greenhouse gases compared to conventional technologies.

**Methane (CH<sub>4</sub>)**

A hydrocarbon that is a greenhouse gas produced through anaerobic (without oxygen) decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and oil, coal production, and incomplete fossil fuel combustion.

**Mitigation**

Any action that results, by design, in the reduction of greenhouse gas emissions by sources or removals by sinks.

**National Environmental Standard (NES)**

Prepared by the Minister for the Environment under S.43 of the Resource Management Act to prescribe limits or methods for environmental matters. Includes the control of greenhouse gases.

**Nitrification inhibitor**

Products that reduce the conversion of various forms of nitrogen into nitrate and nitrous oxide.

**Nitrous oxide (NO<sub>2</sub>)**

A powerful greenhouse gas emitted through soil management practices, animal wastes, fertilizers, fossil-fuel combustion, and biomass burning.

**Nutrient depletion (nutrient mining)**

Refers to the process that slowly depletes the soil of its mineral constituents (i.e., mainly phosphorus [P], potassium [K], and nitrogen [N]). These are essential plant nutrients to crops. Depletion may take 5–50 years before the soil can no longer support economically sustainable cropping. The process is common on marginal soils where crop residues are not recycled.

The nutrient balance, which assumes a negative value under depletion, refers to the difference of the inputs of nutrients into a farm (or catchment, region or country) from fertilizers, manure, biological N fixation, rainfall) and the outputs (in crop harvests, leaching, erosion). Plants also absorb micronutrients (including Ca, Mg, Fe, Zn, Cu) in small quantities. Correction of the negative balance was long considered unnecessary, but micro-nutrient deficiencies are increasingly showing up in food crops and in human nutrition. Appropriate fertilizers can remediate this problem.

### **Offset**

Compensating for the effects of activities through other means. Offsetting greenhouse gas emissions could include planting trees, using nitrification inhibitors, or improving the energy efficiency of farm operations.

### **On-site effects, off-site effects**

Effects are observed at the same location or area or beyond. Off-site effects are often not included in economic evaluations of practices.

### **Participatory**

Means “with the people:” designing and implementing intervention strategies should occur together with all stakeholders.

### **Permanent Forest Sink Initiative**

Allows landowners to get the economic value of removing carbon dioxide from the atmosphere and sequestering (storing) it in the form of new forests.

### **PGGRC**

Pastoral Greenhouse Gas Research Consortium

### **Plains, lowland plains**

Refers to the area downstream of headwaters, and upstream of coastal zones, and exclude the urban and peri-urban areas. Plains are usually flat and contain most of the agricultural activities.

### **Post-2012 negotiations**

Negotiations already commenced that aim to agree on an international framework for addressing climate change following on from the first Commitment Period of the Kyoto Protocol.

### **Potential productivity**

Biological production in conditions where inputs are not limiting and where management is optimal. It is used as a reference value for the current level of productivity and “yield gap.”

### **Price-based instruments (measures)**

An intervention that encourages or discourages practices by changing the price of or creating a price for activities which emit or absorb greenhouse gases.

### **Resilience**

A property of complex ecosystems and society to withstand external pressure without significant internal change. Pressure beyond a threshold causes the system to collapse.



**Revenue recycling**

The return to the economy of revenue derived from a policy measure.

**Rumen**

The stomach of a ruminant animal.

**Ruminant animal**

Cloven-hooved mammals that digest their food in two steps include: cows, sheep, deer, and goats.

**Salinization**

Is the process of building up concentrations of salt in water or soil to levels that reduce or prevent crop growth.

**Seawater intrusion**

Is the process of seawater moving through the subsoil into the land. If it reaches the surface, salinization of soil and surface water occurs. The process occurs when freshwater near the coast is extracted from the soil.

**Sequestration**

The uptake and storage of carbon. Carbon can be sequestered (stored) by plants as organic material or by industrial processes such as pumping deep underground.

**Sink**

Any process, activity or mechanism that removes a greenhouse gas or a precursor of a greenhouse gas from the atmosphere.

**Sink credits**

A *sink credit* is a unit derived from a forest sink activity that results in a net removal of greenhouse gases.

**Soil organic matter (SOM)**

Is the remainder of plants, animals, and microbes in the upper layers of the soil and contains carbon (40 percent), nitrogen (0.1–1 percent), phosphorus, potassium and other plant micro-nutrients. SOM enhances the soil water-holding capacity.

**Technology transfer**

The set of processes that covers the exchange of knowledge and goods among different stakeholders; and leads to the dissemination of technology for adapting to or mitigating climate change.

**Threshold**

Criteria that define which firms, sites, or other business units are required to participate in a policy measure.

**Tradeable permit regime**

A situation whereby a government allocates permits to industry members to cover all or some of their current greenhouse gas emissions. Members are liable for emissions above the level of emission permits they hold.



**UNFCCC**

United Nations Framework Convention on Climate Change, negotiated in 1992. It aims to stabilize greenhouse gas concentrations at levels that avoid dangerous human interference with the climate system.

**Urban and peri-urban areas**

Refer to those parts of the river basin where people and land and water management are strongly affected by large concentrations of people. This refers to cities with more than a few hundred thousand inhabitants, and particularly to mega-cities of several million persons plus the area with horticulture and animal husbandry that surround them. Most of these cities are in the lower parts of basins, often at or close to the coast. Important exceptions include the highland cities of Mexico, the Andes, and the Himalayas. Peri-urban and urban agriculture (PUA) refers to very intensive, small- and large-scale agriculture, particularly horticulture, floriculture, poultry and pig production that occur in or near cities. It is characterized by its strong ties to urban life and markets, more so than by geography. PUA is a major consumer of city wastes (liquid and solid), but contributes to groundwater pollution and health hazards.

**Voluntary Greenhouse Gas Reporting (VGGR)**

A system whereby sector participants voluntarily report their emissions to a central registry in accordance with a prescribed and standard format.

**Waste water**

Is water from households and cities that has been used domestically, and often contains urine and feces of humans and animals, plus organic remainders of food preparations; wastewater may contain valuable plant nutrients, but is often a carrier of diseases and heavy metals.

**Water**

Refers to all surface water in rivers, lakes, reservoirs, wetlands, and aquifers. Water quality includes both the change in the availability of water (increases or reductions) in quantity, the contents of particles and dissolved materials, and contamination with diseases.

**Water productivity**

Is the quantity of produce, measured in weight or monetary terms per unit of water, and can be determined at the plot, farm, catchment and basin scale.