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PROCEEDINGS OF THE REGIONAL LAND DEGRADATION ASSESSMENT IN DRYLANDS (LADA) WORKSHOP FOR SOUTHEAST ASIA

LADA

Land Degradation Assessment in Drylands

FIAT PANIS

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OF

THE REGIONAL LAND DEGRADATION ASSESSMENT IN DRYLANDS (LADA) WORKSHOP FOR SOUTHEAST ASIA

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Foreword

Land and water resources are the foundation for agricultural production, fisheries and aquaculture that provide nutrition and income to people, together with other products for food, fuel, fodder and building materials. Further, ecosystem services associated with land and water — including surface and groundwater restoration, regulation of extreme climatic events such as floods and droughts and maintenance of biological diversity — provide crucial benefits to both rural and urban populations. Especially in environmentally fragile areas such as upland and mountainous regions where the majority of the poor and marginalized live, deforestation, overgrazing and intensified cultivation have led to soil erosion and fertility losses, increased flood and drought incidents and altered water flow patterns.

Over the past 30 years, the natural environment of Asia and the Pacific region has been subjected to increasing degradation of both land and water resources thereby threatening livelihoods, food security, people's health and long-term sustainable development. This difficult situation is further exacerbated by growing populations, urbanization, widespread poverty, ineffective governance, ambiguous property rights, weak institutions and inappropriate policies.

Pressures on land, forest, water and aquatic resources in Asia and the Pacific are more severe compared to other regions of the world. Some 850 million hectares, representing more than 28 percent of the region's land area, are affected by some form of land degradation. Deforestation, inappropriate agricultural practices, inefficient irrigation water use, excessive groundwater extraction and industrial development continue to contribute to land, soil and water degradation and coastal erosion. Soil erosion and nutrient mining have reduced the agricultural potential of vast areas. The quality and quantity of water resources in the region are also under great stress due to expanding demands for growing agriculture and industrial uses, and urbanization.

Crucial to addressing poverty and food security in the region is effective and equitable land and water resource management for resource-based livelihoods. The ongoing threat of climate change adds additional stress to fragile ecosystem services on which the rural poor rely. Improved approaches, which respect sustainable local practices and recognize the integral relationships of resources and production ecosystems, are required to strengthen resilience to managing future challenges, uncertainties and negative impacts.

In Asia and the Pacific region, processes leading to land degradation of particular concern include erosion, compaction, acidification, declining soil organic matter, weed infestation, soil fertility depletion and biological degradation. However, available data on the extent of land degradation are limited and weak. Many efforts have been implemented in recent decades to understand, assess and monitor land degradation in general and desertification in particular. Until recently there was no mechanism in place to collect and disseminate comparable information within countries, across regions and at the international level. To respond to the need for up-to-date and comparable land degradation information, the Global Environmental Facility (GEF) has funded the Land Degradation Assessment in Drylands (LADA) project to be implemented by the United Nations Environmental Programme (UNEP) and executed by the Food and Agriculture Organization of the United Nations (FAO). The LADA project has developed tools and methods for land degradation assessment and built capacity at national, regional and international levels to analyse, design, plan and implement interventions to mitigate land degradation, and identify, establish and support sustainable land-use and land management practices. The capacities developed and the knowledge bases produced by LADA constitute a platform for policy-making at national and global levels.

The aim of this current initiative is to extend and apply the knowledge, tools and experiences created by LADA to the Asia–Pacific region. It will help to promote and assist governments and the international community to mitigate land degradation, desertification, deforestation and loss of biodiversity; the approach will be recognized as critical towards reducing hunger, alleviating poverty and achieving more integrated planning and management of land resources for the improved management of the environment. In this context, the workshop was organized to examine and discuss the current LADA methodologies for land degradation assessment and planning, to consider the need for additions and to re-emphasize support for sustainable land management in Southeast Asia.

He Changchui
Assistant Director-General and
FAO Regional Representative for Asia and the Pacific

Acknowledgements

The workshop was ably hosted by the Land Development Department (LDD), Ministry of Agriculture and Cooperatives (MOAC) of Thailand under the effective coordination of the LDD Workshop Organizing Committee.

Country reports came from seven Southeast Asian countries (Cambodia, Indonesia, Lao People's Democratic Republic, Myanmar, the Philippines, Thailand and Viet Nam) and one East Asian country (People's Republic of China) represented by the Chinese LADA team member.

Technical contributions were also provided by Dr Riccardo Biancalani, Dr Des McGarry and Dr Livia Peiser. Gratefully acknowledged is Dr Freddy Nachtergaele, Senior Officer and LADA Coordinator for his overall support in organizing the LADA regional workshop.

We wish to thank the LDD soil and water conservation group lead by Mr Sakda Sukviboon and Mr Somsak Sukchan for organizing a most informative field trip.

Contents

Acronyms and abbreviations

ARIS	Agricultural Resources Information System (Philippines)
ASSOD	Soil Degradation in South and Southeast Asia
BSWM	Bureau of Soils and Water Management (Philippines)
CBD	Convention on Biological Diversity
CLUP	Comprehensive Land Use Plan (Philippines)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CST	Committee on Science and Technology
DPSIR	Driving force–pressure–state–impact–response
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environmental Facility
GIS	Geographic Information System
GLASOD	Global Assessment of Human Induced Soil Degradation
GLCN	Global Land Cover Network
IIASA	International Institute for Applied Systems Analysis
ISRIC	International Soil Reference and Information Centre
IUCN	World Conservation Union
JICA	Japan International Cooperation Agency
LADA	Land Degradation Assessment in Drylands project
LARIS	Land Resources Information System (Philippines)
LDD	Land Development Department (Thailand)
LUD	Land Use Division (Myanmar)
MAS	Myanmar Agriculture Service
MOAC	Ministry of Agriculture and Cooperatives (Thailand)
MOAI	Ministry of Agriculture and Irrigation (Myanmar)
MODIS	Moderate Resolution Imaging Spectroradiometer
MOWRAM	Ministry of Water Resources and Meteorology (Cambodia)
MRC	Mekong River Commission
NAP	National Action Plan for Sustainable Land Management (Cambodia)
NAP	National Action Plan (Philippines)
NAP	National Action Programme (Viet Nam)
NDVI	Normalized Difference Vegetation Index
NPP	Net primary productivity
REC	Regional Economic Commission
RGC	Royal Government of Cambodia
RUE	Rainfall use efficiency
SAFDZ	Strategic Agriculture and Fisheries Development Zone (Philippines)
SLM	Sustainable land management
SMSS	Soil Management Support Services (USDA)
SWAT	Soil and Water Assessment Tool
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNU	United Nations University
USDA	United States Department of Agriculture
VSA	Visual Soil Assessment
WASWC	World Association of Soil and Water Conservation
WOCAT	World Overview of Conservation Approaches and Technologies

1. Background

Rising populations have put increasing pressure on land resources for greater food production. The area of cropland in Asia and the Pacific expanded from 210 million hectares in 1900 to 470 million hectares in 1994, largely at the expense of forests and woodlands. In addition, agricultural yields have dramatically improved in the last 40 years, largely due to the green revolution. The combination of extensive deforestation and unsustainable agriculture, together with inadequate soil conservation, cultivation of steep slopes, overgrazing and rapid urban and industrial growth has had a devastating impact on land resources. Land degradation processes of particular concern in Asia and the Pacific include soil erosion, compaction, and acidification; declining soil organic matter; weed infestation; soil fertility depletion and biological degradation.

Much effort has been expended in the last few decades in order to understand, assess and monitor land degradation in general and desertification in particular, but available data on the extent of land degradation are limited and weak. Until recently there has been no mechanism in place to collect and disseminate comparable information within countries, across regions and at the international level. The available data on the extent of land degradation are limited and there are only two studies (Global Assessment of Human Induced Soil Degradation [GLASOD] and Soil Degradation in South and Southeast Asia [ASSOD]) with global coverage, but both have considerable weaknesses such as lack of remote sensing or field measurements and being based on expert opinion only. However, in the absence of anything better, they have been widely used as a basis for national, regional and global environmental assessments.

LADA started in 2006 with the general purpose of creating the basis for informed policy advice on land degradation at global, national and local levels. This goal is to be realized through the assessment of land degradation at different spatial and temporal scales and the creation of a baseline at the global level for future monitoring. LADA has developed tools and methods to assess and quantify the nature, extent, severity and impacts of land degradation on dryland ecosystems, watersheds and river basins, carbon storage and biological diversity at a range of spatial and temporal scales. It has also built national, regional and international capacity to analyse, design, plan and implement interventions to mitigate land degradation and establish sustainable land-use and land management practices.

The participating countries — Argentina, Cuba, the People's Republic of China, Senegal, South Africa and Tunisia — plan to initiate the process for establishing regional training 'centres' or to train for scaling-up of LADA in-country and over the wider region. In response to a request for guidance, the Committee of Science and Technology of the United Nations Convention to Combat Desertification (CST/UNCCD) noted its recent review of institutional capacities and decision to link with centres of excellence and Regional Economic Commissions (RECs) for training and scaling-up of sustainable land management. The capacities developed and the knowledge bases produced by LADA constitute a platform for policy-making at national and global levels. All the information is made available to interested parties through workshops, publications, web-based information systems and the increased expertise of the national organizations involved.

With these developments and needs, the FAO Regional Office for Asia and the Pacific in collaboration with the Land Development Department (LDD), Ministry of Agriculture and Cooperatives (MOAC) of Thailand organized the LADA training workshop for Southeast Asian countries.

2. The workshop

Objectives

The overall objective of the LADA training workshop for Southeast Asian countries was to learn, discuss and exchange LADA methodologies for adaptation at local, national and regional levels and degradation assessment and planning for sustainable land management including project proposal preparation.

The workshop activities included:

- Presentation of country papers;
- Lectures on LADA methodologies, global, national and local assessments, indicators, and LADA information systems;
- Project proposal preparation for LADA support; and
- A field visit.

Participants

The workshop was attended by representatives from Cambodia, Indonesia, Lao PDR, Myanmar, the Philippines, Viet Nam and Thailand. The LADA team delegation numbered the representative from LADA China, the LADA technical advisor and the natural resources expert at FAO headquarters. The LADA technical expert in field soil assessment tools introduced and demonstrated the methods devised. A total of 55 participants attended the workshop.

Opening of the workshop

On Monday 27 April 2009, after registration of the participants, the opening session took place at LDD, Bangkok with welcome remarks and introduction of participants by Dr Rungsun Im-Erb, Chairman of the Workshop Organizing Committee of LDD. This was followed by a welcome address from Mr Hiroyuki Konuma, Deputy Regional Representative, FAO RAP and an opening address by Mr Kasem Thongpan, Deputy Director-General, LDD.

Presentation of the LADA project, tools and other assessment programmes

The LADA technical advisor, Dr Biancalani, introduced the LADA project and global LADA activities, followed by LADA techniques, tools and land-use systems, national questionnaires and national and local-level assessment. Dr McGarry, the LADA technical advisor and the natural resources expert introduced and demonstrated the VS-Fast field soil assessment tools and the development of indicators for agricultural ecosystems under sustainable management. The representatives of the World Association of Soil and Water Conservation (WASWC) and LDD introduced the Soil and Water Assessment Tool (SWAT).

Presentation of country papers

Country papers describing the nature of land degradation, availability of information and the importance of georeferenced data, causes and origin of land degradation, methodologies, mapping and modelling in-country were presented. Other issues included were legal, economic and social aspects in government policies and strategies for assessing and monitoring land degradation, institutional set up and coordination at local and national levels, the role of private sectors, farmer participation and extension services.

Cambodia

The major causes of land degradation in Cambodia are deforestation by war, unsustainable agricultural and water management practices, land-use changes for development and industrialization. The process of desertification is impacting every aspect of agricultural productivity, loss of natural resources and socio-economic conditions. Combating desertification and drought is the national priority. To adequately respond to the urgent needs of climate change, in particular droughts and floods, a draft National Adaptation Programme of Action to Climate Change has been prepared containing priority actions needed to adapt to climate change with regard to agriculture, water resource management, coastal zone management and human health.

China

Serious land desertification threatens China’s ecological security and sustainable socio-economic development as well as the subsistence and development of the nation. In order to master the status quo and dynamic changes of desertified land nationwide, provide scientific support and databases for macro decision-making by the central government, the State Forestry Administration has completed three rounds of National Monitoring Surveys for Desertification since 1994. The findings of the surveys provide support for the decision-making process for ecological development and combating desertification and the implementation of a forestry development strategy with ecological development as a priority.

Indonesia

The growing population and rapid demand for land for settlement in Indonesia has resulted in shifting of agricultural land uses to non-agricultural activities and increasingly shifts towards use of steep and sloping land and stony areas of uplands. This has caused declining productivity and increasing food insecurity. Land degradation assessment is necessary to recognize the strategic and real problem and monitor land degradation. Agrosilvipastoral systems can restore degraded land and conserve land and water resources.

Lao PDR

During the last decades of the twentieth century, the loss of forest land in Lao PDR rapidly increased due to various land-use practices, such as shifting cultivation, commercial logging, commercial agriculture and tree plantation. There is a plan to assess forest cover and land-use change from 2002 to 2012. There is a need for land degradation assessment.

Myanmar

The national economy of Myanmar largely relies on agricultural and forestry products and land degradation is a major threat and challenge to the economy and communities. Land evaluation assists basic resource survey results being used for land-use planning. A Land Resources Information System is considered vital to ensure environmentally valuable land resources are used and managed sustainably.

Philippines

The quality and management of land resources in the Philippines has become a serious concern because of increasing population and expansion of agricultural lands. Accelerated erosion is the most common form of land degradation in the Philippines followed by nutrient mining and soil fertility decline. There are land degradation assessment maps on hot spots and bright spots. Currently, data updating is project-based and localized.

Thailand

Some studies on land degradation in Thailand were conducted in 1994 and 1995 based on the FAO–UNESCO *Soil map of the world*. The assessment results were reliable and indicated the magnitude of degradation and risk.

Viet Nam

Several policies and programmes/projects to combat land degradation are being implemented. The National Action Programme (NAP) on Combating Desertification 2006–2010 towards 2020 was initiated in 2006 to upgrade the effectiveness and efficiency of forest resource management, strengthen land-use management, improve the management of water resources, mitigate the adverse effects caused by drought and meet the present needs of people in affected areas.

Field trip

A one-day field trip was organized to visit the degraded land area in Nakhon Ratchasima Province.

Group discussion

The group discussed the overall issues regarding land degradation, LADA methodologies and approaches and regional collaboration. The general findings were:

- The methodology of the LADA project is comprehensive and adaptable;
- The LADA methodology is consistent and based on scientific principles;
- The proposed assessment methods can be applied with little adaptation and also in subhumid and humid areas; and
- The relevance of the institutional and capacity building component of the LADA proposal.

Findings

- The LADA methodology was well accepted by the participants. The entire methodology was described and a practical exercise was carried out. This reinforced the presentations and gave a better idea of the method;
- There are large differences in the way that land degradation assessment is dealt with in the various countries. The introduction of a common assessment methodology could be beneficial for better mutual understanding and sharing of experiences; and
- The fact that LADA contains 'drylands' in its nomenclature is a matter of concern, as it may give the (wrong) impression that the methodology does not address the other needs of countries. A change of wording or a shift in focus has been suggested.

Conclusions and recommendations

1. The introduction of the LADA methodology within the context of the respective national strategies is to combat land degradation and to be used as a coordination tool at regional and subregional levels within the existing institutional arrangements.
2. The participants considered LADA is important in terms of assessment, monitoring, planning, capacity building and land resource management. The participants want to be pro-active in demonstrating and quantifying changes in land use; LADA is a tool for coming up with baseline data on land degradation and for monitoring the efforts of governments in alleviating the long-term impacts of interventions.
3. Establishing regional networks for diverse users to share expertise, knowledge and experiences. In particular, sharing of experiences among Southeast Asian country experts participating in LADA especially in the standardization of protocol and region. Also expected are capacity building, institutional strengthening and technical cooperation.
4. At the national level, LADA approaches are expected to contribute to national action programmes, monitoring, assessment and planning. LADA methodologies are to be used for creating inventories, national maps and harmonization of existing data.
5. Expected support and funding from participating countries should include contributions in cash and kind.
6. Each country targets GEF country allocation on land degradation as the primary focus for support, and for regional programmes, GEF-5 is to be targeted for support in the longer time frame.

Technical Reports

The Land Degradation Assessment in Drylands (LADA) project 2009

Abstract

Much effort has been expended in the last few decades to understand, assess and monitor land degradation in general and desertification in particular. Until recently there has been no mechanism in place to collect and disseminate comparable information within countries, across regions and at the international level. To respond to the need for up-to-date and comparable land degradation information, the Global Environmental Facility (GEF) has funded LADA to be implemented by the United Nations Environmental Programme (UNEP) and executed by the Food and Agriculture Organization of the United Nations (FAO). The present project started in 2006 and will terminate in 2010.

The project has two main objectives:

- *To develop and implement strategies, methods and tools to assess, quantify and analyse the nature, extent, severity and impacts of land degradation on ecosystems, watersheds and river basins, and carbon storage in drylands at a range of spatial and temporal scales;*
- *To build national, regional and global assessment capacities to enable the design, planning and implementation of interventions to mitigate land degradation and establish sustainable land-use and management practices.*

LADA considers land degradation to be a complex phenomenon with different aspects that need to be evaluated together in order to get a complete picture and to be able to envisage the most appropriate responses.

Land degradation is the reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for its beneficiaries.

According to the approach adopted by LADA, seven key assets of ecosystems are defined in a way that makes it easier to relate them to goods and services provision, thus providing a more consistent basis to quantify their relevance in relation to land degradation assessment.

The LADA project benefits from the active participation of all LADA countries. A number of other countries and regional organizations have asked for participation but there is no financial mechanism in place under which this can be accommodated.

Parties to the UNCCD embarking on national land degradation assessments are encouraged to adopt the LADA methodological framework and to share their findings for refining the global LADA assessment. Parties interested in refining the findings from the global LADA assessment in their own countries are welcome to request LADA assistance to develop project proposals and to identify potential funds. Parties that are in a position to assist financially in this endeavour are invited to do so.

Freddy Nachtergaele, Riccardo Biancalani and Sally Bunning
FAO, Viale delle Terme di Caracalla, Rome, Italy

Introduction

Much effort has been expended in the last few decades to understand, assess and monitor land degradation in general and desertification in particular. Until recently there has been no mechanism in place to collect and disseminate comparable information within countries, across regions and at the international level. To respond to the need for up-to-date and comparable land degradation information, the Global Environmental Facility (GEF) has funded the Land Degradation Assessment in Drylands (LADA) project to be implemented by the United Nations Environment Programme (UNEP) and executed by the Food and Agriculture Organization of the United Nations (FAO). This project has benefited from the support of the United Nations Convention to Combat Desertification (UNCCD), the International Soil Reference and Information Centre (ISRIC), the United Nations University (UNU), the Global Land Cover Network (GLCN) and other regional and national partners. The present project started in 2006 and will terminate in 2010. It has been prepared through a PDF-A phase (2000–2001) and a PDF-B phase (2002–2004).

Pilot countries

Six countries participate in the project as pilot countries: Argentina, Cuba, the People's Republic of China, Senegal, South Africa and Tunisia.

Main objectives of the project

- To develop and implement strategies, methods and tools to assess, quantify and analyse the nature, extent, severity and impacts of land degradation on ecosystems, watersheds and river basins, and carbon storage in drylands at a range of spatial and temporal scales;
- To build national, regional and global assessment capacities to enable the design, planning and implementation of interventions to mitigate land degradation and establish sustainable land-use and management practices.

As a result of this land degradation assessment the following outputs should be achieved:

- The baseline, trends and driving forces of land degradation in drylands globally;
- The status of land degradation at national and subnational scales and identification of the driving forces and pressures leading to resource degradation for the pilot countries;
- Developed and harmonized participatory local and national assessment tools;
- An analysis that identifies cause–effect relations between the different indicators of land degradation within the Driving Force–Pressure–State–Impact–Response (DPSIR) conceptual framework;
- A global action plan containing all the findings of the project as well as conclusions and recommendations for further action.

Time frame

The project was approved by the GEF in November 2004 and commenced activities in May 2006. It has a four-year duration up to April 2010; a no-cost six-month extension based on the results of a mid-term evaluation is under consideration (up to October 2010).

Structure of the project

The project operates at different levels of scale. It has a global-level component, which is based partly on remote sensing information, partly on modelling of global databases and complemented by ground-truthing work. The country level has two components: a national component that combines (global) land-use principles and datasets with land degradation information collected at the national level through expert knowledge, and a local-level component that is based on fieldwork and local expertise.

Global level

Global component

The global component consists basically of four work directions:

a) Land-use system mapping at the global level: Global land-use systems are developed at FAO and adapted to the needs of a land degradation assessment. They are based on the analysis of sets of biophysical and socio-economic data (climate, soil and terrain, land cover crops and livestock and management interventions). The resulting map is refined in national planning assessments. The map units are characterized using biophysical and socio-economic data as DPSIR indicators. These mapping units are the cartographic basis for the national assessment, and the framework in which the local assessment takes place (and as such allows extrapolation from global to local and from local to global).

b) A global study of pressure indicators associated with land degradation: FAO together with the International Institute for Applied Systems Analysis (IIASA) undertook a detailed global study to study the evolution of the aridity index, rainfall intensity, status of land cover, soil vulnerability and slopes that are all thought to have a significant influence on soil erosion. The results have been published and are also available in map format.

c) A study of the trends in Net Primary Productivity (NPP) and Rainfall Use Efficiency (RUE) through the analysis of NDVI (Normalized Difference Vegetation Index) data: This method takes into account 21 years of NDVI data. They are then converted into NPP and RUE. Those areas where both the RUE and the NPP have constantly decreased over the years are considered as hot spots for this specific indicator, while the areas where they have increased are noted as bright spots. Note that the method determines vegetation health trends corrected for rainfall and temperature variations. This is one important aspect of land degradation but it does not capture the whole issue comprehensively. This method has been developed by ISRIC and has been tested in China and in Kenya in the framework of LADA. Global results have been published and are available; derived and ground-checked national results are available in LADA countries.

d) A study of land cover change to agriculture and urbanization through the analysis of Landsat data: This method has been developed by the Global Land Cover Network (GLCN). It uses a comparison between the current land cover as it appears from the most recent Landsat images and the situation as it appears in two other series of images taken in the 1970s and the 1980s. Those areas where there has been a change from forest or rangeland to agriculture or urbanization will be considered hot spots for this indicator. Results are available for Kenya and Senegal and studies are underway in South Africa, Tunisia and Cuba.

Country level

Based on the results of the preparatory studies, a seven-step approach has been formulated, which is considered the modular part of the LADA methodological framework at national and local levels. The seven steps of the LADA approach are:

1. Identification of land degradation problems and users’ needs assessment.
2. Establishment of a LADA task force.
3. Stocktaking and preliminary analysis.
4. Stratification and sampling strategy.
5. Field surveys and participatory assessment.
6. Information integration.
7. Monitoring strategies and tools.

National component

LADA's national component is carried out by national institutions in partner countries supported by the project. It consists basically of the collection and analysis of locally available data, processing the data to make them compatible with international standards and their comparison with the results of global studies. Consequently, these countries are able to refine and detail the maps obtained under the global study and to have a national cartographic base for land degradation assessment. Further development includes the establishment of a national land degradation information system online in a specific LADA website.

National expert knowledge characterizes the land-use systems' base map with land degradation and land management characteristics at the subnational level. A specific mapping tool, in the form of a questionnaire, has been prepared by the project in collaboration with the World Overview of Conservation Approaches and Technologies (WOCAT). This tool allows the application of national knowledge in a more consistent and comparable way among different countries. The results from this exercise are compared with the hot and bright spots identified at the global level, and serve as a basis to guide the local assessment survey described hereunder.

Results at the national level are already available for Tunisia and Senegal; those from other LADA countries will follow soon.

Local component

Local assessments are being carried out in areas selected by each country following the national land degradation assessment. Each participating country has initiated detailed assessments for at least two sites, supported by national-level policy forums to create the linkage processes to local by-laws, national planning and development practice. The training of relevant professionals in land degradation assessment, impact analysis and related developmental factors is ongoing and nearly complete. These assessments will be made according to low-cost and swift procedures; they will follow a participatory approach to obtain stronger involvement of the local stakeholders. The local component aims at identifying not only the actual status and circumstances of land degradation, but also its historical development and the perception of it by people. This will allow a better understanding of the phenomenon and will provide pertinent information for the definition of response measures. The local assessments analyse indicators in the DPSIR framework, taking into account both biophysical and socio-economic indicators. The detailed assessment methodology is defined in guidelines prepared in collaboration with all LADA countries, the University of East Anglia, the Fast Visual Soil Assessment group and WOCAT.

The local assessment activity also allows for ground truthing of the national and global assessments.

Integration of the different levels

LADA aims at integrating the findings of the local, national and global assessments, both horizontally and vertically.

Horizontally, harmonization of the assessment methodology among countries has been conceived for making comparable results and to allow easier communication and experience exchange among the pilot countries and other countries willing to adopt the LADA approach. Both the national approach and the local approach were developed harmoniously with all LADA partner countries.

Vertically, using harmonized methodology for the creation of the land-use systems' base map allows for the establishment of linkages between findings at the global level and the country-level components that are used to compare the results at different levels of scale.

Holistic approach

LADA considers land degradation to be a complex phenomenon with different aspects that need to be evaluated together to obtain a complete picture and to envisage the most appropriate responses.

Land degradation is the reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for its beneficiaries.

According to the LADA approach, seven key assets of ecosystems are defined in a way that makes it easier to relate them to goods and services provision, thus providing a more consistent basis to quantify their relevance in relation to land degradation assessment. The seven assets are.

1. Social and cultural benefits.
2. Maintaining biodiversity.
3. Soil health.
4. Water quality and quantity.
5. Opportunity value.
6. Biomass: total organic carbon production.
7. Biomass increment.

They are represented in Figure 1.

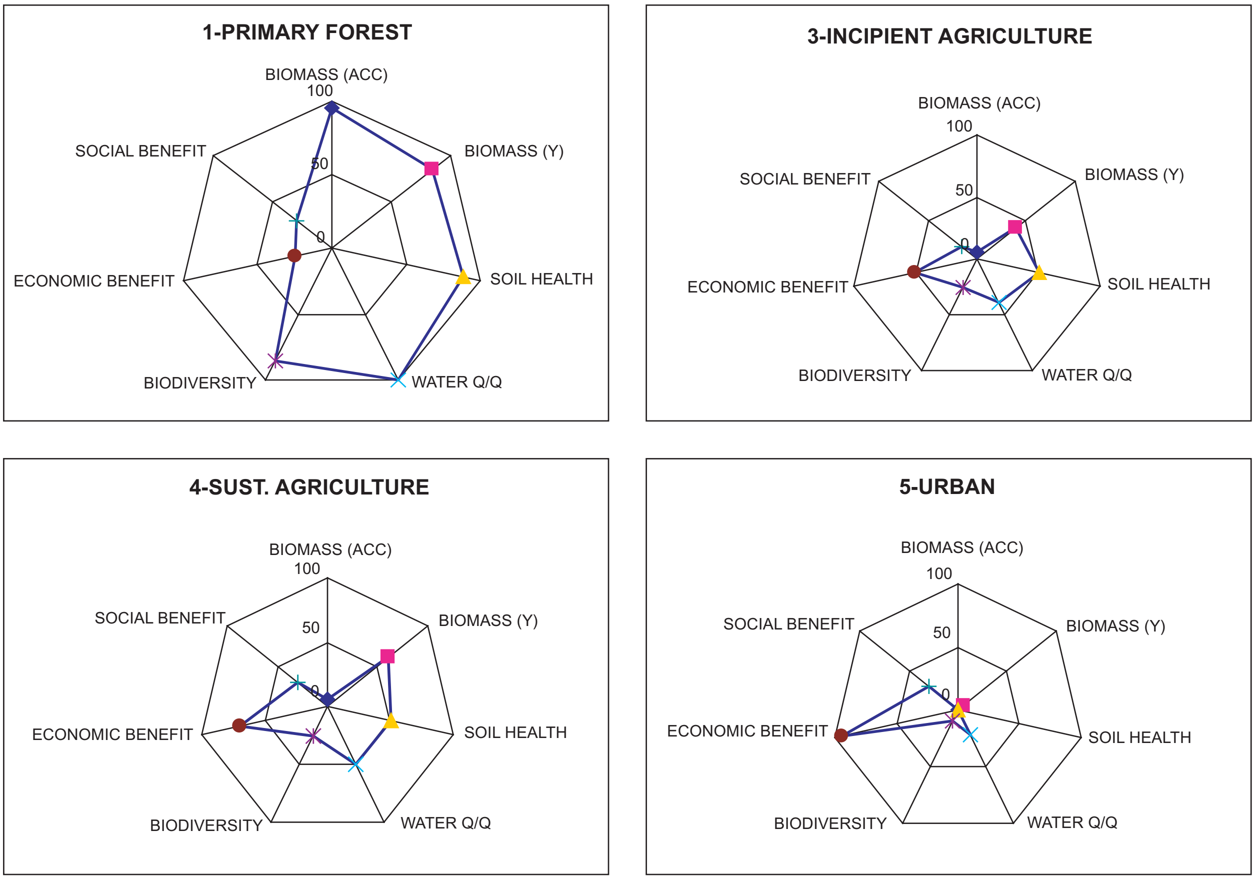

Figure 1. Transformation of land use and consequent changes in ecosystem goods and services: forest cutting and introduction of agricultural activities. 1a. 1980: Primary forest. 1b. 1987: Subsistence agriculture. 1c. 1996: Sustainable agriculture (improvements implemented). 1d. 2002: Urban settlement (transformed into building land)

This complexity is dealt with in two ways:

Multiscale: The multiscale approach allows addressing different issues at the most appropriate level of scale, although at all levels (global, national and local) both biophysical and socio-economic aspects are taken into consideration. This is done through the assessment of different indicators, or different ways to assess the same indicator. This allows giving each user more pertinent information according to needs, as outlined below.

User's perspective: The user's point of view is particularly important in the LADA methodology. This is because different users may have quite different perspectives on a matter, to the point that what is a degradation indicator for one is an improvement for another. LADA recognizes this situation in order to provide decision-makers with a more complete set of information.

The LADA approach

LADA has four main project components:

1. Development of the LADA approach: land degradation assessment guidelines, and a network and information system.
2. Carrying out global and regional land degradation assessments.
3. Carrying out local assessments in hot spots and bright spots in pilot countries.
4. Carrying out a major analysis and preparation of a strategy for global action.

For each component, the following corresponding outcomes are attached:

1. An improved needs-based and process-driven approach to dryland degradation assessment tested and disseminated at global, national and local levels.
2. Global and national maps with information on land degradation indicators.
3. Detailed local assessments and analysis of land degradation and its impact in the pilot countries.
4. A proposed global action plan, incorporating main findings from the project, conclusions and recommendations for further action.

This LADA approach integrates biophysical and socio-economic components of land degradation at different scales, recognizing that socio-economic issues are also driving forces of pressures that impact on land conditions.

The LADA approach further recognizes that land degradation assessments should:

- Capitalize on existing initiatives,
- Focus on the goods and services of the drylands,
- Work with local stakeholders, and
- Make use of a standardized methodology that allows monitoring of land degradation over time.

It also recognizes that humans are integral components of most ecosystems and emphasizes the understanding of the immediate and underlying causes of threats to biodiversity; this leads to policy and management interventions at appropriate levels. The LADA approach applies the integrated approach to ecosystem management at local, land-use system and national levels.

The LADA methodological framework comprises the LADA approach and a set of tools for the different scales of land degradation assessment from the global level to the subnational level. It incorporates participatory rural appraisals; expert assessments; field measurements; remote sensing, geographic information systems (GIS), modelling and other modern means of data generation, processing and dissemination for analysing and sharing information.

The key elements of this strategic approach are:

- Participation and inclusion of different perceptions of land degradation;
- Combination of hard data, expert assessment and local knowledge; and
- Use of adapted assessment tools for specific environments.

To understand the process of land degradation at subnational, national and global levels, the LADA approach relies on the DPSIR framework. The DPSIR framework states that driving forces exert pressures on the environment and that these pressures can induce changes in its state or condition. The subsequent impacts on socio-economic and biophysical attributes cause society to respond by developing or modifying environmental and economic policies and programmes aimed at preventing, minimizing or mitigating pressures and driving forces.

The adoption of this conceptual framework also implies the recognition of the dynamic nature of the land degradation phenomenon. Land degradation in this way is defined by comparison with a previous situation, when driving forces exerted a certain pressure on the land. This pressure created the present state of the land, which is having an impact that will drive a response in the future.

The time factor is thus introduced in the system and it has been considered in the formulation of the assessment methodology at all levels.

Indicators' toolbox and visual soil assessment tool

During the PDF-B phase the LADA project started developing an indicator toolbox that contains a minimum set of indicators that can be measured at local and global scales; it allows for extrapolation at these different scales. Development of the toolbox continued during the full-scale LADA project. The LADA indicators are relatively easy to measure or obtain and are therefore inexpensive. The LADA indicators are related to several land conditions in such a way that they can describe the system in a cost-effective way. This includes information on land-use systems, on soils, on vegetation/biodiversity and on water resources.

The LADA project has also developed a specific local assessment tool — a set of simple and inexpensive assessment techniques which can be learned gradually by farmers and which are related to their needs for improving land conditions. These Visual Soil Assessment (VSA) indicators are morphological and measure soil characteristics that allow for the transfer of information between sites, soil types, land uses, etc., while providing a cross-check and physical reality to structure descriptors.

Capacity building

Capacity building is one of the main objectives of the project. At all stages of interventions, substantial attention is given to training, institutional and technical capacity building. Particular emphasis is put on multistakeholder involvement and participation, especially to benefit land users, farmers and the rural poor at the local level and policy-makers at national and global levels. Local professionals and extension agents are trained in field assessment of land degradation by adopting a farmer perspective and using a sustainable rural livelihoods' approach. Best practices also identify the synergies between different global benefits (biodiversity, climate change, international freshwater basins/river systems) and between global and local benefits (food security, livelihood support, and poverty alleviation).

It is worth noting that the capacity building activity will have a special focus at the regional level, through the establishment of six regional training centres in pilot countries on land degradation issues. The regional centres will be created with the collaboration of the national partners; their trainers will be prepared and the curricula are being defined.

Relevance of LADA for policy

The new capacities and knowledge base that are being produced by the project will constitute a foundation for more aware policy-making at national and global levels. All the information will be made available to interested parties through workshops, publications, web-based information systems and the increased expertise of the national and international organizations involved.

LADA will communicate and exchange land degradation information to complete the linkage to the policy process and decision-making. It will do this through policy guidance (in, for example, UNCCD Regional, Subregional and National Action Programmes), GEF and implementation agency interventions in land degradation control and the identification of priority actions, such as policy and institutional reforms and development investments at all levels. Communication and exchange will be furthered by the implementation of best practices' studies to identify lessons learned and means to check and reverse land degradation issues and providing support to monitoring activities on the changing severity of land degradation and the effectiveness of remedial control measures.

Conclusions and recommendations

The LADA project benefits from the active participation of all LADA countries. A number of other countries and regional organizations have asked for participation but there is no financial mechanism in place under which this can be accommodated. In particular, LADA outputs provide background information to support UNCCD strategic objectives 1, 2 and 3. Parties to the UNCCD embarking on national land degradation assessments are encouraged to adopt the LADA methodological framework and to share their findings for refining the global LADA assessment. Parties interested in refining the findings from the global LADA assessment in their own countries are welcome to request LADA assistance to develop project proposals and to identify potential funds. Parties that are in a position to assist financially in this endeavour are invited to do so.

Areas of agricultural ecosystems under sustainable management: building on LADA achievements

Abstract

This paper focuses on FAO's development of the indicator 'areas of agricultural ecosystem under sustainable management' at a global scale, within the framework of the GEF-supported 2010BIP project. The paper outlines notable challenges in measuring sustainability and proposes the use of a proxy indicator 'areas of agro-ecosystems under management strategies and practices which support sustainability' as a practical alternative. The use of LADA and other related specialist networks in the eventual global compilation of this proxy indicator is briefly explored.

Introduction

In response to biodiversity loss, in 2004 the Convention on Biological Diversity (CBD) identified several focal areas and related indicators that could be used to monitor and report on country progress towards the 2010 target, adopted in 2002, "to achieve a significant reduction of the current rate of biodiversity loss at global, regional, and national levels as a contribution to poverty alleviation and to the benefit of all life on earth". The 2010 Biodiversity Indicator Partnership project (2010BIP) was set up by the GEF to coordinate and facilitate the development of indicators by various organizations that will be used to assess and report on progress by countries toward the 2010 target. The immediate objective of the project is to better inform governments and other stakeholders so as to improve the conservation status of biodiversity at the global level.

The current phase of the BP2010 project (2007–2010) focuses on indicator development and testing, while a second phase of implementation is envisaged. This paper outlines a draft methodology for development of the indicator on "Areas of agricultural ecosystem under sustainable management" at the global level. It solicits feedback from practitioners, specifically those involved in the ongoing Land Degradation Assessment in Drylands or LADA project (LADA 2009), on the validity of the proposed draft methodology in geographic areas with which they are familiar. It also solicits their collaboration in the eventual collective compilation on a country-by-country basis of the required information during an envisaged second phase of the 2010BIP project.

Agro-ecosystems and sustainability

Mapping agro-ecosystems

Agricultural ecosystems or agro-ecosystems have been defined by FAO as "ecosystems that are used for agriculture in similar ways, with similar components, similar interactions and functions. Agro-ecosystems comprise polycultures, monocultures, and mixed systems, including crop-livestock systems, agroforestry, agrosilvipastoral systems, aquaculture as well as rangelands, pastures and fallow lands. They are found all over the world from wetlands and lowlands to drylands and mountains and their interactions with human activities, including socio-economic activities and socio-cultural diversity, are determinant" (FAO 2009).

A major challenge in developing the indicator at the global level is determining the extent of agro-ecosystems, given the limitations in reliability of available maps in delimiting the non-cultivated components of agro-ecosystems. Owing to this difficulty, this draft report presents separately, for evaluation, the results for 'cultivated systems' and 'agro-ecosystems'.

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Sustainability

Sustainable use has been defined as "Human use of an ecosystem so that it may yield a continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations" (Millennium Ecosystem Assessment 2005).

It is now widely established that multiple evaluation criteria, spanning three key dimensions — economic, social and environmental or, alternatively, five livelihood capitals (social, financial, natural, physical, human) — must be satisfied to enable sustainable management of agro-ecosystems. Sustainability can only be evaluated over time. Evaluation criteria must therefore be periodically monitored at relevant scales of interest (e.g. field, farm, community, watershed, ecoregion, ecozone, global, etc.) in order to assess sustainability.

At the community level, sustainability has been successfully assessed using participatory, stakeholder-based approaches in which stakeholders identify and agree on the locally important criteria that they will use for assessing the impacts of planned actions or changes (e.g. Herweg and Steiner 2002). Stakeholders select the various thresholds for each criterion distinguishing what is acceptable from that which is not. Failure to reach acceptable levels on one or more criteria implies 'unsustainability' of the proposed changes. Community-level approaches are necessarily location specific. They are set within a local socio-economic setting and reflect local values and priorities. Such stakeholder-based approaches are therefore not applicable in developing a global indicator on the sustainability of agro-ecosystems.

In view of these difficulties and in order to develop a practical methodology, which would yield results within a reasonable time frame, it is proposed to use the proxy indicator 'area of agro-ecosystems under management practices which support sustainability' as a substitute for 'area of agro-ecosystems under sustainable management'.

The presence of interventions supporting sustainability (e.g. land and water conservation practices) does not necessarily imply that the associated agro-ecosystems are sustainable. However, it could reasonably be argued that the management aim in the adoption of such land and water conservation practices is often the sustainability of the agro-ecosystems. Hence, for global-level analyses, 'area of agro-ecosystems under management strategies and practices supporting sustainability' is proposed as a proxy indicator for 'area of agro-ecosystems under sustainable management'. A similar indicator has been proposed for Europe Agriculture: area under management practices potentially supporting biodiversity (European Environmental Agency 2007).

Management practices and strategies supporting sustainability

Many resource management interventions support sustainability and conserve biodiversity. Specific strategies and practices are relevant only at certain spatial scales (Table 1). Undertaking national-level inventories of such interventions in all countries may be used in compiling the indicator, using a 'building block' approach, to obtain global coverage. Data collected at the national level would be aggregated, as needed, to yield regional and global statistics. A benefit of this approach is that it retains sufficiently detailed information for monitoring, establishing interlinkages and guiding subsequent decision-making over a range of scales — from subnational to global.

Towards a global inventory

A major immediate challenge in compiling a global inventory of 'the area of agro-ecosystems under management practices that support sustainability' is that relevant data on land use and management are not uniformly available globally, in terms of content, data quality and spatial detail (George and Nachtergaele 2002). This lack of harmonization is addressed in the LADA–WOCAT land degradation assessment manual that contains a structured schema and catalogue on management practices (Liniger *et al*. 2008). Table 2 is an extract of sustainable practices/technologies covering crops, livestock and forestry, currently available within the LADA–WOCAT manual.

Table 1. Scales of applicability of various strategies and practices contributing to sustainability (based partly on the outcomes of FAO consultations, 2007) and relevant potential data sources

Scale	Sustainable management intervention	Potential information sources for global mapping
Global National Watershed	Eco-regional strategies – integrated watershed management – integrated grazing land management	– expert knowledge – LADA–WOCAT studies
Community Farm Field	Specific conservation practices – crop rotations – organic additives – structural (e.g. terraces)	Detailed surveys – agricultural projects, research – field observations

In practice, the manual is used to guide ‘consensus’ descriptions of current land management practices in different land-use systems by a local team of interdisciplinary experts, knowledgeable in land conservation and degradation. Results are aggregated by administrative district in order to facilitate geographic targeting and prioritizing of interventions by decentralized government entities. A key advantage of the methodology is its relative rapidity and low cost (because it is based on expert knowledge). The use of ancillary data is encouraged in order to minimize the subjectivity associated with this expert-knowledge driven process.

While the current LADA–WOCAT ‘catalogue’ needs to be expanded to cover the range of sustainable interventions related to livestock systems, forestry and fisheries within agro-ecosystems in greater detail, it already offers a harmonized method for the characterization of management practices across all major sectors (crops, livestock, forestry, fisheries). This is a key requirement for ensuring consistency in a global survey based on contributions from multiple countries.

Table 2. Management practices and measures available in the LADA–WOCAT manual of potential use in guiding national inventories of management practices supporting agro-ecosystem sustainability (Liniger *et al*. 2008)

LADA-WOCAT conservation technology groups	Specific measures
Agro-forestry Afforestation and forest protection Conservation agriculture Coastal bank protection Grazing land management Nutrient management Other Protection against natural hazards Gully control/rehabilitation Rotational systems Groundwater/salinity regulation/water use efficiency Storm water control, road runoff Sand dune stabilization Terraces Vegetative strips Water harvesting Water quality improvement	Agronomic: mixed cropping, contour cultivation, mulching, etc. Vegetative: grass strips, hedge barriers, windbreaks, etc. Structural: terraces, banks, bunds, constructions, palisades, etc. Management: land use change, area closure, rotational grazing, etc. Combinations of the above measures.

Exploratory study: Senegal

An analysis was undertaken of the data that were collected on management practices during the LADA national-level assessment in Senegal (Centre de Suivi Ecologique 2007). An initial step in national-level assessment is the mapping of all land-use systems — geographic zones characterized by similar natural resource bases, actual land uses and socio-economic conditions, following an approach developed by George and Petri (2006) (Figure 1). Area-wise, the extent of the various management practices supporting sustainability was evaluated and subsequently mapped for each land-use system within each of the 34 departmental administrative districts of Senegal (Figure 2). The extent of such practices, for the cultivated component as well as for all agro-ecosystems, is presented in Figure 3.

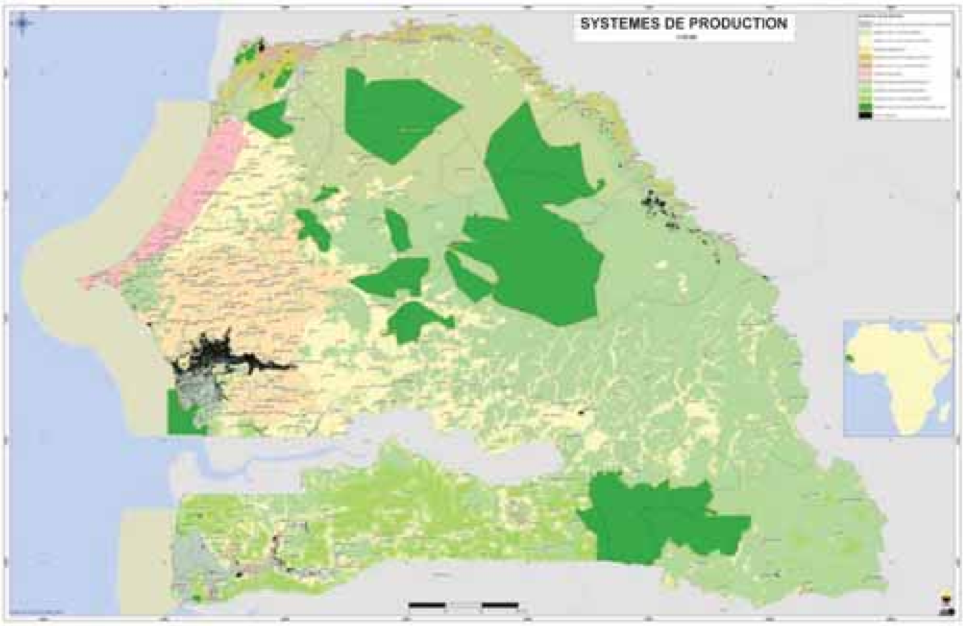

Figure 1. Map of the major Senegalese land-use systems overlain with administrative boundaries (Centre de Suivi Ecologique 2007). Observations on land-management practices within each land-use system are aggregated to each administrative unit

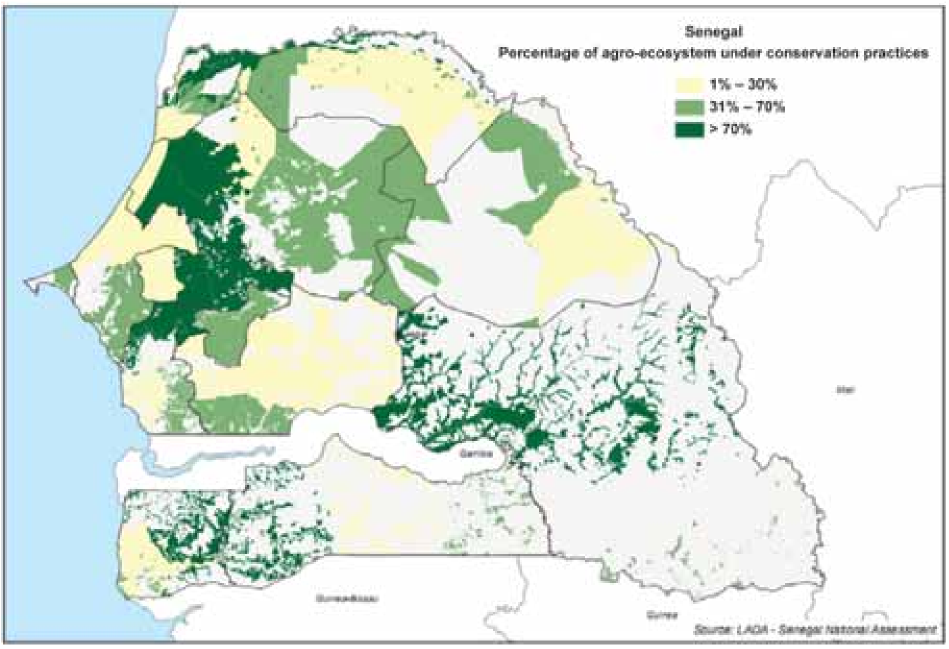

Figure 2. Total extent of area under management practices supporting sustainability — all types.

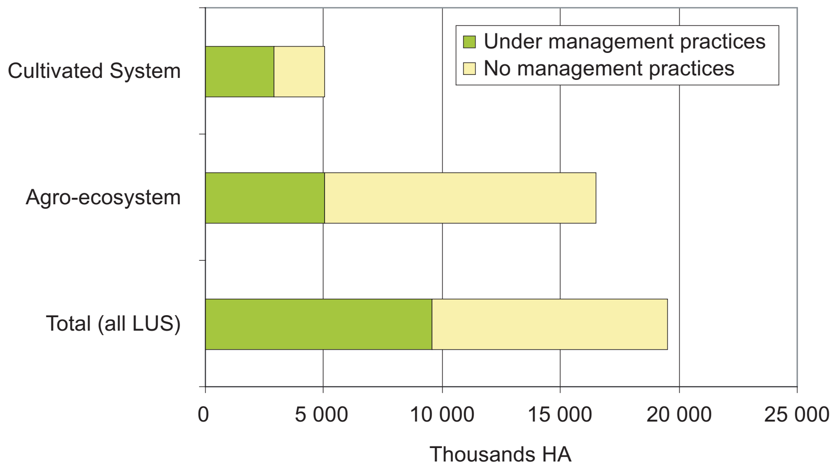

Figure 3. Extent of area under management practices that support sustainability in Senegal

It is envisaged that development of the indicator at the global level would require similar country-level studies focused on an inventory of management practices (i.e. a subset of the observations required for full LADA national assessment). As discussed next, currently available global data sets could be used to prioritize the collection of data on countries where agro-ecosystems are under the highest sustainability pressures.

Areas of highest sustainability pressures

Selected global data sets covering environmental factors were used to derive a map indicating relative pressures on the sustainability of cultivated systems. The specific factors used were: Declining net primary productivity, negative land balance per capita, cropland per capita, potential cropland expansion (net land balance) per capita, presence of natural land cover, proportion of renewable water resources withdrawn for agriculture and a key socio-economic factor linked to poverty (infant mortality).

Increasing values of each of these component indicator data sets are associated with increasing pressure on the resource base supporting agro-ecosystems (in the case of the environmental factors) or with lowered levels of social acceptance (for the poverty indicator). By arbitrarily assuming that the values in the highest two percentile classes (nine percentile classes used in this study) represent a hot spot for that indicator and by looking for places where one or more indicator hot spots coincide, a global map of relative pressure on agro-ecosystem sustainability has been prepared (Figure 4). This map is potentially useful in prioritizing areas for a detailed inventory of management practices.

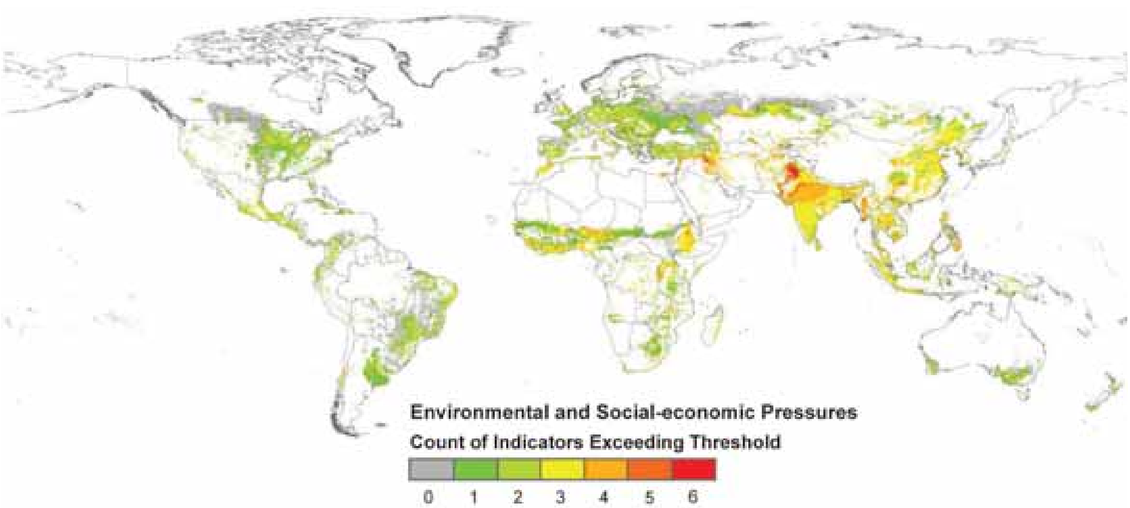

Figure 4. Areas with highest pressure on the sustainability of agro-ecosystems

Concluding remarks

Evaluating the sustainability of agro-ecosystems requires simultaneous consideration of multiple criteria (social, economic and environmental) over time. While practical approaches have been applied successfully at community scales, it is not feasible to apply similar methodologies at regional to global scales, where many different communities and socio-economic factors of varying local relevance and importance would come into play. The extent of management strategies and practices that support agro-ecosystem sustainability is therefore proposed as a proxy indicator for 'the extent of agro-ecosystems under sustainable management', for global-scale studies.

Currently, only limited country-wide data exist for this indicator, notably for the LADA pilot countries, where the data were collected as part of national land degradation assessment activities of the project. Building a consistent global indicator by applying LADA methods in all countries would require considerable time, effort and commitment by many national entities. A proposal is under study for simplifying the LADA national assessment methodology, which would allow expert-based country estimates to be provided online, to achieve global coverage within a reasonable time frame. Feedback from regional experts in Asia and other geographic regions, as well as LADA partner networks, will be evaluated in finalizing the draft methodology.

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The VS-Fast field soil assessment tools in LADA

Introduction

A set of methodologies has been developed to facilitate the collection and interpretation of pertinent soil properties within the Land Degradation Assessment in Drylands (LADA) project of the Food and Agriculture Organization of the United Nations (FAO). The methodologies, termed 'VS-Fast', are several interrelated and integrated, qualitative and quantitative assessments of soil in the field.

As such, VS-Fast provides a 'toolbox' of techniques to measure the current state and extent of land degradation in the world's agricultural lands, rationalize causes and advise on restoration programmes, the effect of which can be monitored by reapplication of the VS-Fast techniques. The techniques in VS-Fast have been carefully chosen and their methodologies presented in such a way as to ensure that they are accurate, reproducible (in space and time) and reliable; several of the techniques provide quantitative outputs. They are all indicators of soil properties, commonly accepted as being directly affected by land management (both negatively and positively). Though 'simple' in use and equipment requirements, all of the techniques are scientifically robust, providing strong and defensible outcomes.

Techniques cover the range of visual/tactile observations of soil excavated by spade (soil depths,* texture* and colour,* structure* [pans and dry-aggregate size distribution], crusts,* earthworms* [or other suitable soil fauna indicator species] and roots*); the techniques also address aggregate dispersion, pH, water infiltration, organic matter (labile carbon) and electrical conductivity (salinity) of soil and local waterbodies (the latter where pertinent). Primarily designed for use by technical staff, with training, many of the tools in VS-Fast are certainly employable by farmers (those marked *); they require no more than a spade and some observational powers to achieve multilevel understanding both of the farmland as well as the impact(s) of current farming practices, both negative and positive. All of the techniques are designed to be used in the field to provide immediate and visual indications of soil quality, quickly interpretable by farmers and landowners present during testing. Additionally, ten of the techniques (out of 13) generate quantitative data on soil quality and condition; score cards for these factors are provided to enable comparisons between soil at the detailed assessment sites. Hence through quantitative benchmarking and by reapplying the same techniques, a basis for monitoring over time is provided, particularly if new, more sustainable land practices are introduced and need validation of success.

For consistency and comparability it is important to conduct the complete set of core measurements at all selected detailed assessment sites. If this is not done then the scores cannot be combined to give the integrated scores of quality. Additional measurements can be taken and other indicators used to assess the soil where appropriate or preferred locally.

Each of the techniques will be presented in turn. The complete methodologies are presented in the LADA-L Manual Part 2, currently in the final stages of editing, prior to publication. To ensure links to the manual, the same numbering system of the LADA-L Tools referred to will be followed here.

Clearly, not all of the following tests are suitable for all soil types and the interpretation of the results can also change between soils. For example, rapid hydraulic conductivity, that indicates good soil structure in a clay or loam, is an unattractive attribute in a sand — showing rapid drying of the soil, following rain or irrigation. Also, soil crusts are not always a negative attribute. These possible ambiguities in the interpretation of results are discussed in the relevant sections below.

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1. Tools 2 and 3: Site Map and Transect

The initial site inspection utilizes Tools 2 and 3 — the Site Map and the Transect. These tools are designed to provide an overview of the state of the land and major features of interest (land uses, visible degradation, more sustainable land management [SLM] areas, soil types, topography, vegetation and crops, settlements, etc.) as well as to aid location of subsequent detailed assessment sites at selected, key spots. Both tools are best conducted in participation with local land users and land/soil experts, using their input and utilizing their local knowledge to locate the detailed sampling sites and give them 'ownership' of subsequent outcomes.

Specifically in terms of the VS-Fast techniques, whilst walking the transect many, rapid, 'one-spadeful' holes are dug to provide both a rapid overview of soil types, anthropogenic impacts, soil–vegetation relationships and to aid location of subsequent detailed assessment sites. As a general rule, the ratio of these one-spadeful holes to detailed VS-Fast assessment sites will range from 20:1 to 50:1.

Box 1. Comparative sampling within VS-Fast

The VS-Fast techniques, as with almost all the techniques in the LADA-L Manual, are based on comparative assessments where one site is compared with a closely adjoining site that differ in some key attribute or process. It is important to select plots that are relatively close to each other if valid comparisons are to be made, as sites far apart may differ in soil type and other qualities that will affect susceptibility of the land to degradation and the impact of the degradation on measured properties. Examples of comparative assessments include plots (areas of land) where there is visible land degradation in one but not in the other; differences in vegetation cover (or crops), health and composition; agricultural ground with relatively 'untouched' adjoining tree or fence lines; plots with differences in conservation/restoration measures/management practices that impact on land degradation and its restoration (e.g. grazed vs. non-grazed; no till vs. conventional cultivation).

2. Tools 9 and 10: Interview with Land User and Site Photograph or Sketch

These tools collect descriptive information of the sites (fields/plots) that will be subjected to the detailed assessments. Both are crucial to facilitate **interpretation** of the subsequently collected VS-Fast data. In terms of the interview with the land user, the topics given here (Box 2) should be considered more as a check list as it is difficult to provide a comprehensive list that is applicable to all situations. At the most general level, the interview should cover items of management and environmental history, both current and historically (the last five to ten years). It is important to ask additional questions and/or explore additional areas if raised during discussion and relevant, and to investigate trends and changes when appropriate, e.g. changes in land degradation and people's perceptions of its effects or the extent to which land users engage in conservation/SLM.

The site photograph or sketch is important to provide both a summary/overview of the local geography and land features (water, vegetation, field sizes, crops, etc.) as well as a record of the management context in which the land degradation is being assessed and the juxtaposition of the various degradations. Notations on the sketch or photo can also show the locations of subsequent observation/measurement locations. Photographs should also be taken of the soil surface (looking down from above — i.e. from head height), to record surface soil structure (crusts) and vegetation/crop residue cover.

Box 2. Suggested interview questions with local land users

- land-use change (ha) — increase/decrease in crop, pasture, range, forest, etc.,
- livestock grazing system (seasons, free/tethered/fenced/kraaled),
- access rights (owner, communal area, lease, etc.),
- pasture improvements (seeding, removal of invasive species etc.),
- forest (type, health, yield — above or below expectations),
- crops (type, health, yield — above or below expectations),
- land preparation/tillage: type, direction and depths,
- power: hand, animal, tractor (size),
- presence of minimum or no till (and for how many years/seasons),
- crop residues (kept in field, removed — partially or totally, etc.),
- fertilization (and response to) — organic (includes manures) and mineral,
- other soil ameliorants applied, e.g. lime, gypsum,
- land levelling (and if in specific areas of the site),
- rainfall (recent and historical), for example 'very wet at last harvest',
- attempts at introducing 'best' or altered practices,
- land degradation observations — location, type, history, apparent causes,
- water for domestic and agricultural use:
  - additional water resources besides rainfall used (streams, boreholes)?
  - problems with availability of water, flooding, water quality?
  - difficulties in accessing water (rules, laws, ownership issues)?
  - changes (in the last one, five, ten years) in quality, quantity, access to water?

Again, several advantages are gained if the site photograph or sketch is conducted with the land user:

- It is a good 'ice-breaker', engages the land user in a positive way and indicates the land user's perspective on the land,
- It provides both location of land degradation features as well as the land user's concerns (or otherwise) of the same,
- It provides an initial record of the land user's assessment of the limitations of each land unit and how they have changed over time.

3. Tool 12.1: Soil Visual Indicators

The observations and measurements in this tool are based on the examination of a spadeful of soil at a site selected for detailed assessment.[1] Comparative assessments are the norm (see Box 1). A spade with a flat (though usually slightly curved) blade is used to remove an intact 'block' of soil, commonly up to 30 or 40 cm deep and 25 cm wide from the site under investigation. The soil is left on the blade of the spade for subsequent observations. The spade, with the block of soil on the blade, is commonly propped-up on a rock or against a car or fence for description, sketch or photograph. The soil zones of greatest interest in terms of VS-Fast occur from the soil surface to approximately 40 cm depth. This represents the most important zone for seedbed development, early germination and plant growth, as well as being the zone with the greatest potential for negative impacts on water infiltration, soil carbon losses, etc. from wind and water erosion, and soil compaction.

[1] When the sites for detailed assessment are chosen, it is important to georeference them — commonly using a handheld GPS unit to record latitude and longitude, as well as height above sea level. These data can be entered into software such as Google Earth™ to not only record the sampling site location for future revisiting and resampling but also to place the site in the broader landscape context.

Seven visual indicators of soil quality, determined on the excavated soil block with supporting information from the soil surface around the excavated pit, are recommended for the core LADA-L assessment. With the exceptions of soil depth, texture and colour, guidelines are provided for their scoring and the integration of these scores into a soil quality assessment.

Soil depths: Firstly, using a measuring tape, ruler or stick graduated in centimetres, assess and measure the location of any visible soil layers in terms of colour, soil structure (pans), root density, etc.

Record. Note these depths on the field sheet, supported by a sketch of the soil profile, annotated with depth and principal soil features. A photograph of the excavated soil block on the spade is also strongly recommended.

Texture: Soil texture refers to the relative proportions of sand, silt and clay size particles in a soil sample. Texture has important effects on a wide variety of soil properties, e.g. soil's water holding capacity, aeration and porosity, hydraulic conductivity, compaction potential, resistance to root penetration, nutrient holding capacity (i.e. cation exchange capacity) and resistance to acidification.

Method. Take one or two tablespoonfuls of soil (from a soil layer of interest) in one hand and add water, drop by drop, to the soil as it is being worked in the hand until a sticky consistency is reached. The soil is then rolled into a ball and texture determined, through the ability to form various shapes from the rolled ball (Figure 1).

Record. Note the texture class determined on the field sheet.

Structure: The description of soil structure focuses on the presence of 'pans' in the soil (platy and massive, continuous, horizontal layers) and a dry-aggregate size test (drop-shatter test) on the excavated block of soil, dropped from a prescribed height to facilitate breakages along natural lines of weakness.

Tillage pans (formed by mechanical implements such as ploughs or hoes) and other forms of pans are important negative indicators of soil condition as well as being symptomatic of non-sustainable land management practices. Soil pans are located and described by comparing the lower and upper parts of the excavated spadeful of soil. Tillage pans only occur in cultivated land, either from metal implements working soil or repeated trafficking by tractors, both giving the worst compaction (tillage pan) when conducted in moist to wet soil. Other types of pans can be found in grazing and fodder producing lands (e.g. growing perennial grass swards). In these situations the pan is commonly on the immediate soil surface, resulting either from surface trampling by animals or from repeated passes of harvesters and balers, cutting and packing animal fodder.

Record. Note the scores for the presence, thickness and degree of development of a soil pan range from 'good' condition where a pan is not present to 'poor' where a massive or platy pan is present with few or no vertical cracks.

The (dry) aggregate size distribution test, here, aims to bring some uniformity to the method of manipulating the soil (on the spade) and to get it to break along natural cleavage planes.

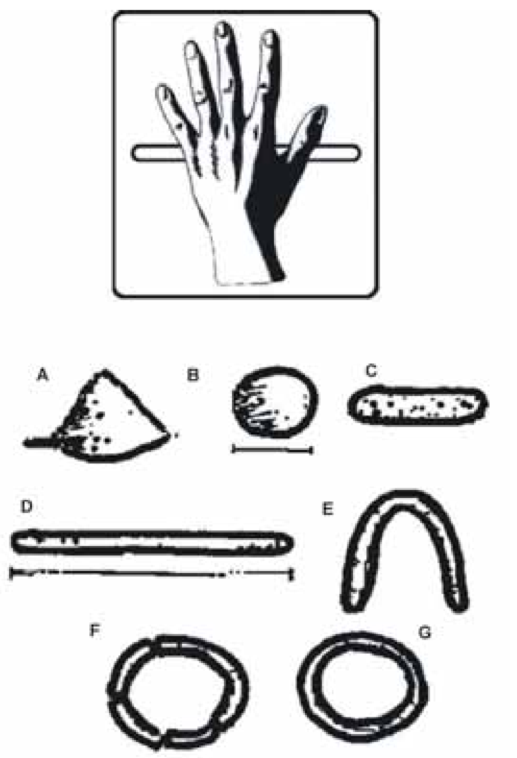

Figure 1. Field-derived soil textures: A (sandy), B (sandy loam), C (silty loam), D (loam), E (clayey loam), F (fine clay), G (heavy clay)

Method. In the drop-shatter test a spadeful of soil is dropped three times from a uniform height (commonly waist height) either onto a plastic sheet (lying on the ground) or into a rectangular-shaped 'washing-up' basin. If the soil does not completely shatter into individual units, then gentle hand manipulation is used to break the soil along natural cleavage lines. Once the soil is broken into its individual aggregates, these are sorted so that the largest are placed at the top of the plastic sheet and the smallest at the bottom. Degraded soil tends to have a greater proportion of coarse and firm structure units than a well-structured soil where small units predominate.

Record. Note the scores for good, moderate and poor condition; ranging from 'good distribution of friable small aggregates with no significant number of soil clods', to 'soil dominated by large, extremely firm clods with very few small, friable aggregates'.

Soil crusts: These are soil surface phenomena, comprising a consolidated layer commonly <10 mm thick that can be separated from and lifted off the soil beneath, on drying. Most commonly regarded as a negative soil feature, in certain circumstances they can have positive effects on soil and landscape health. Crusting is most common in fine-textured soils (loams and sands), though clays with low aggregate stability (see the stability test below) from high sodium levels and/or low organic matter content can also crust. In such soils, soil crusts impact negatively on soil health by reducing water infiltration (hence increased erosion risk, prolonged water ponding in flat and concave areas and reduced water storage in the soil) as well as reducing seedling germination. The degree of negative impact increases with both greater crust thickness and continuity (i.e. less cracking). Examples of 'positive' crusts are so-called 'biological' crusts that consist of a hard crust, held together by lichen-/moss-type materials. These types of crust are specific to arid, desert areas (e.g. Northwest China), where their widespread occurrence has a strong positive impact on soil and landscape condition by binding the soil surface, hence greatly reducing wind erosion (specifically wind-blown sand).

Record. Note the scores for 'negative' crusting, ranging from good, where there is little or no surface crusts to poor, where crusts are present, up to 10 mm thick and are continuous with no cracking. Positive crusts are scored oppositely with good being a continuous (biological) crust and poor, no crust present. A photograph of the surface crust is recommended.

Soil colour: Colour indicates many important soil properties, including the source material(s) of the soil and the climatic/human factors that have altered the original rocks and sediments to give the current soil condition. Soil colour is also a strong indicator of current soil water (or aeration) status, where bright colours, and reds and oranges in particular, show good soil aeration and drainage. Dull and grey colours show reduced aeration and a tendency for low-oxygen status and waterlogging. The dull grey/black colours in a waterlogged soil often occur as mottles, i.e. a secondary colour within the main soil colour. Soil colour may also reflect the organic matter status of the soil, particularly useful when comparing the topsoils of long-term cropping land with treelines and fencelines. Generally, the darker the soil, the greater the organic matter content.

Record. Describe the soil colour (red, black, brown, etc.) on a slightly moistened lump of soil from the layer of interest. If present, describe secondary colours (e.g. mottles and organic stains).

Earthworms and other soil biota: The presence of soil biota usually indicates good soil quality. Earthworms are particularly good at incorporating organic matter into the soil, increase soil fertility via their caste material and improve aeration (burrows) with associated improvements in water infiltration and crust prevention. Additionally, the presence of many earthworms reflects and integrates many positive aspects of soil condition: good aeration (no waterlogging), structure (no compaction), plentiful food supply (for earthworms, the retained crop residues and stubble) and the lack of disturbance by cultivation (no till). As such, the presence of biota is a most important, and fortunately in terms of the macro-biota, an easy-to-record attribute. Earthworms, however, are rarely found in sandy soils and may only occur in deep soil layers of arid (infrequently wetted) landscapes; hence they are a poor indicator species for soil health in such situations. In such circumstances the presence of termites, ants, beetles and collembolan (commonly called 'springtails') may provide alternate indicators of good soil condition, as well as causing the development of fertile soils. Ants are known to move and aerate considerable quantities of soil, and termites affect both nutrient pools and the flow of water into the soil through their interconnected galleries. Currently, research is limited on the link between the presence and abundance of ants and selected termite types and their use in monitoring soil condition. With all soil biota, it is important to recognize that they are seasonal and migratory animals (constantly seeking warmth, food, moisture and softer soil). Consequently, it may well be that during a soil inspection earthworms (and other soil indicator fauna) are not found but evidence of their earlier presence is visible, namely earthworm burrows (large, round and continuous pore spaces) in the soil profile and caste (faecal) material on the soil surface, termite burrows and mounds, buried stores of organic material, etc. In the absence of actually capturing and counting earthworms and other soil fauna, the number and concentration of related soil fauna features should be noted.

Method. While manipulating the soil on the spade blade for soil structure description, pick out and place to one side all earthworms found in the soil sample.

Record. If the spadeful of soil is a 20 cm cube that equates to a 1/25 square metre of soil, multiply the numbers of earthworms by 25 to convert to a square metre basis.

Roots: The development of root systems into the soil is a prime biological indicator of soil and vegetation condition. Where plant root growth is not impeded it will reach its optimal form (root depth, lateral spread, density of roots and root hairs) and optimize the uptake of water and nutrients to meet plant demand. However, when root growth is impeded by rocks, hard or compacted soil layers, high groundwater or saturated conditions, nutrient deficiencies, salinity or toxicity, or water shortage, the result will be visibly stunted or deformed roots that in turn will lead to restricted growth of aboveground parts of the plant (Box 3). Triangulation with other indicators/observations will help identify the specific causes of the root deformations.

Box 3. Observations of plant roots

- evidence of stunted/deformed roots or acute, sharp changes in root penetration into the soil (L-shaped roots, particularly evident in tap-rooted crops like cotton and sunflower),
- disproportionate number and concentration of roots in the immediate surface layer, demonstrating that extension into the layers beneath is difficult,
- concentration of roots on ploughpans — at the greatest depth of ploughing,
- evidence of roots ‘squashed’ in fissures between strong soil units, demonstrating their inability to penetrate into these units,
- absence of fine root hairs, or an overabundance of strong primary roots, showing the difficulty experienced by the fine roots to penetrate the soil.

Method. Determine the extent and development of the plant root system by examining the root system emanating from the sides of the block of excavated soil (on the spade blade) and similarly, as the excavated block of soil is manipulated and broken up for soil structure description.

Record. Score from good to poor, being from unrestricted root development to severe restriction, including L-shaped roots, overthickening or roots squashed between soil units.

4. Tool 12.2: Assessing Soil Properties

Five soil properties are measured and the recorded scores integrated with those in Tool 12.1 to give an overall value for soil quality assessment. The soil measurements here have been chosen for a combination of simplicity, reproducibility and rapidity, focusing on measures that are directly affected by land management. When at all possible, the VS-Fast field soil measures and tests should be conducted at the assessment sites.

Not only does this allow an immediate sharing and discussion of findings with land users but it is also possible to record (photograph) a permanent site record of the pH test (in the porcelain plate) alongside the result of the dispersion test (samples from the same depth in the dispersion dishes) alongside the soil profile on the blade of the spade. Used in conjunction with Tool 10, the Site Photograph and Sketch, this gives an additional lasting record of the site and some of its soil properties at the time of the assessment.

Soil slaking and dispersion: The inherent ability of a soil, and particularly the soil surface, to withstand the impact of several types of land degradation, principally wind and water erosion, is strongly dependent on the soil's response when wetted. There are two main types of aggregate collapse when water is added to soil: slaking, which describes the breakdown of aggregates into micro-aggregates, and dispersion, which describes the breakdown of aggregates into the primary soil particles of sand, silt and clay. The differentiation between slaking and dispersion is most important. Generally, the products of slaking can re-form to produce larger aggregates whereas dispersion into primary particles is irreversible and results in undesirable, massive structure. On the soil surface, dispersed soil appears either as a hard-setting layer (or a surface crust) or as loose fine (white) sand grains. Crusts (see above) and hard-setting are major impediments to both water penetration (causing rainwater to pond on the soil surface with strong potential for erosion) as well as seed germination. Additionally, fine, loose (dispersed) material on the soil surface has strong potential for wind erosion. The amount of organic carbon in a soil strongly influences the ability of a soil to maintain aggregation (and not disperse) when wetted. Organic matter binds soil particles together, and particularly in sand and loamy soils is the principal material causing aggregation. The determination of the slaking or dispersive nature of a soil is commonly a laboratory test but an appreciation of the phenomenon can be gained in a short time during soil description in the field.

Method. Drop an air-dried aggregate from the layer under investigation into a dish (e.g. a saucer) or a small clear container (glass or cup) containing water (use rainwater or local irrigation water). Ensure the entire aggregate is submerged below the water.

Record. After each ten minutes and two hours (when possible) of immersion, a visual judgement is made of the degree of dispersion of the original aggregate on a scale of 0–4, where 4 is no dispersion (individual mineral particles not visible) to 0 where there is complete dispersion and the whole soil aggregate has broken down into individual particles of sand, silt and clay.

Soil pH: Soil pH measures the molar activity (concentration) of hydrogen ions in the soil solution. It is a negative logarithmic scale, so a decrease of 1 pH unit increases the hydrogen ion concentration ten-fold. At a pH of 7 (neutrality), the activity of hydrogen ions is equivalent to the activity of hydroxyl ions. At pH values less than 7 the soil is acidic, whereas at pH values greater than 7 the soil is alkaline. Box 4 gives negative soil characteristics associated with extremes of soil acidity (pH <6) and soil alkalinity (pH >8).

Box 4. Characteristics of acid and alkaline soils

Strongly acidic soils can have the following negative characteristics:

- aluminium and/or manganese toxicity,
- phosphorus deficiency,
- calcium and/or magnesium deficiency,
- reduced nitrogen mineralization because of restricted microbial activity.

Strongly alkaline soils can have the following negative characteristics:

- surface sealing and crusting problems due to excessive sodium,
- reduced availability of iron, manganese, zinc, phosphorus and copper,
- reduced microbial activity and reduction in fungal population.

The pH test presented here utilizes a field test kit developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia. This field test kit is used by Australian field pedologists (soil surveyors). It is used in the VS-Fast system, in preference to other methodologies of determining soil pH such as (electrical) meters, principally because the pH kit provides a visible output — the coloured barium sulphate. This visible outcome, therefore, lends itself to the 'alignment' and photographic procedure mentioned above, that provides a lasting record of pH with the corresponding, visible soil layers/features.

Method. A small amount of soil from the centre of a layer of interest is crumbed and placed onto a white tile or a piece of flat plastic. Just enough of the black/purple liquid from the test kit (universal Raupach indicator) is added to the soil to thoroughly moisten it, without flooding the sample. The soil and indicator fluid are mixed together (with a clean stick), allowed to sit for two minutes (to let the two react) then the white powder in the kit (barium sulphate) is gently 'puffed' over the mix. A colour will develop in the powder. Match this colour with the closest match on the test kit colour chart.

Record. Note the pH value to 0.5 of unit accuracy.

Water infiltration: A major determinant of the cropping or grazing potential of a soil is the rate and amount of water that can infiltrate either through the soil surface or within the soil profile. Interpretation of the measured rates of hydraulic conductivity is not a straightforward matter because many inherent and anthropogenic factors influence the result in potentially interactive/additive ways: soil texture, soil surface structure (crusts), organic matter levels, soil biota (which can create macropores and channels to the soil surface), etc. However, in this rapid assessment, the prime aim is to gain an indication of the water infiltration rate. Hence, the infiltration rate is classified as fast, medium, slow and very slow. The two classes 'very slow' and 'fast' are considered less suitable for most crops/land uses as they indicate drainage problems/waterlogging and moisture unavailability, respectively. Hence, the systems presented here have two 'tails', with high and low (poor) values at the extremities and medium (good) values in the middle range.

The following method was devised by CSIRO. The aim was to derive a simple method for the rapid estimation of soil hydraulic conductivity. Simplicity, both in apparatus required and the field method, was essential. However, although operationally simple, the method is robust, being firmly based on fundamental, globally tested and accepted soil physical principles.

Method. The procedure requires a 100 mm (length) x 100 mm (diameter) ring (metal or PVC with a sharpened tip). A level area is selected and any loose surface litter is carefully brushed away (to avoid changing the surface structure conditions). If vegetation is present, clip it close to the soil surface and remove the clippings. Place the metal ring on the soil surface and push it a few millimetres into the soil to obtain a seal between the ring and the soil surface but ensuring minimal soil disturbance inside the ring.[2] Pre-wet the soil surface in the ring by applying 50 to 100 millilitres (ml) of water. This is important to reduce the initial, commonly rapid and non-steady state infiltration component of hydraulic conductivity, termed sorptivity (where the soil absorbs water due mainly to capillary forces rather than gravity). After 15 to 30 minutes, add 400 ml of water to the ring (aiming to prevent disturbance of the soil surface), this being equivalent to applying 50 mm of rainfall or irrigation water.

Record. Using a watch or stopwatch, note the time for the water to disappear (infiltrate) into the soil. Tables in the manual allow conversion of the infiltration time to a permeability class: generally being from fast at <1 minute (and regarded as a poor state of water infiltration), to >1 minute but <10 minutes — 'medium' rate

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[2] The method has two variations, one of which will be emphasized here, as it is the more commonly used procedure. When the ring is only pressed a short distance (a few millimetres) into the soil surface this facilitates three-dimensional (3-D) flow — where the water can flow both vertically and horizontally into the soil. Where possible, always use this 3-D method as results will be obtained more quickly and the time data are more sensitive to the hydraulic conductivity. The 1-D method, where the core is pushed to a depth more than the diameter of the ring, is more appropriate when soil cracking or the aggregation of the soil makes it difficult to seal the ring onto the soil without leaks occurring.

and >2 hours — 'slow' and also unattractive (the one exception being flooded paddy rice soils where zero infiltration is 'good').

Soil organic carbon — labile fraction: Most of the functions associated with soil quality are strongly influenced by soil organic matter, especially the small portion that is termed labile or 'active' organic carbon. Most (routine) soil chemical laboratories provide a determination of total soil organic matter or soil organic carbon. This is reported as something generally between 0.5 percent and 7 percent in soil. These cannot be field tests as they are based either on total (high temperature) combustion of a soil sample or require strong chemical reagents. Another problem is that they are insensitive to management practices because they include recalcitrant (inert) forms of organic matter (such as charcoal), which remain unchanged for decades, regardless of management practices.

Techniques have been developed to fractionate carbon on the basis of lability (ease of oxidation) recognizing that these subpools of active carbon may have greater effect on soil physical stability and be more sensitive indicators of carbon dynamics in agricultural systems than total carbon values. The labile fraction of soil carbon is the component of organic matter that feeds the soil food web and is closely associated with nutrient cycling and other important biological functions in the soil. Professor Ray Weil (University of Maryland, USA) has developed a field kit method for the determination of potassium permanganate ($KMnO_4$) oxidizable carbon. In this test a dilute solution of $KMnO_4$ is used to oxidize organic carbon. Generally, in the course of the experimental procedure the greater the loss in colour of the $KMnO_4$ (determined in a colorimeter of set wavelength of 550 nm) the lower the absorbance reading will be, hence the greater the amount of oxidizable carbon in the soil. Use of a small amount of calcium chloride ($CaCl_2$) in the method assists soil flocculation, hence removing the need for centrifuge of the sample to obtain a clear supernatant for analysis.

Method. Add 5 cc of air-dried soil from the layer of interest to 25 ml of the $KMnO_4$ solution (33 mM) and 1 ml of the $CaCl_2$ (0.1 M) in a centrifuge tube, shake for two minutes, stand upright for five minutes, pipette off 1 ml from the top of this solution and dilute to 50 ml with deionized water. Zero the colorimeter with deionized water then measure the absorbance of the sample (soil). From (given) standard curves, calculate the concentration of the $KMnO_4$ left in the sample, then the amount of labile carbon in the original sample as the difference between this value and that of the original $KMnO_4$ solution.

Record. Note the permanganate oxidizable carbon content (g/kg) of the soil sample from the tables provided; it is classed as low, moderate and high — dependent on soil texture (as clay soils require more carbon than loams, than sands to have a comparable effect).

Soil and water salinity: Salinity is the presence of soluble salts in soil or water. Salinity processes are natural processes, however human activities can accelerate them, contributing to long-term land and water degradation. Salinity becomes a land issue when the concentration of salt adversely affects plant growth or limits plant species selection (to salt-tolerant plants) or degrades soil structure (surface crusting and scalding). It becomes a water issue (surface and groundwater) when the potential use of water (for irrigation and human/animal use) is limited by its salt content. Soil salinity generally affects plant growth by increasing osmotic tension in the soil, making it more difficult for the plants to absorb water from the soil. Excessive uptake of salts by plants from the soil may also have a direct toxic effect on the plants. Crops vary considerably in their capacity to withstand the adverse effects of salinity. Saline water, apart from being unpalatable to humans and stock, can also cause direct damage to crop leaves, depending on the concentration of salts, applied through sprinkler irrigation.

Salinity in soils and water can be estimated conveniently from the electrical conductivity (EC) of a soil solution, or directly from a water sample. Many salts dissociate (separate out) to ionic form in water, so the EC of a solution provides a measure of the total concentration of salts. EC is defined as a measure of a solution's ability to conduct electricity, and as such can be used to express salinity levels in soil (a soil extract in water) or water. When salt is dissolved in water the conductivity increases, so the more salt, the greater the EC value. EC is measured by passing an electric current between two metal plates (electrodes) in the solution and measuring how readily current flows (i.e. is conducted) between the plates. EC measures the charge-carrying ability (i.e. conductance) of liquid in a measuring cell of specific dimensions. It is necessary, therefore, to state the units of both conductance and length in considering EC. EC units vary between institutes and countries but most common is the use of 'decisiemen per metre' (dS/m), and commonly at 25ºC, as temperature at the time of measurement affects the result. EC can be measured in the field using a portable EC meter. The Milwaukee- C66 'pen' EC meter has been used in LADA assessments to date, as it fulfils many of the requirements of the testing procedure, including operational range (0 to 10 dS/m), waterproofing, cost, ease of use, light weight and being (automatically) temperature compensated.

Method. Ensure the EC pen is calibrated with a standard EC solution (instructions are supplied with the pen). Take 50 to 100 g of soil from the layer of interest, remove all stones and vegetation (roots and residues), prepare a soil paste (saturation extract) by stirring deionized water into the soil in a cup until a smooth, 'just glistening' paste is achieved. Insert the probe of the EC pen into the paste.

Record. Note the reading (given in millisiemens per cm on the pen's readout that is equivalent to dS/m, the preferred reporting units). After reading, clean the tip of the pen with deionized water (and a soft toothbrush) ready for the next sample.

Discussion and conclusions

Testing of the applicability, usability and acceptance of the VS-Fast methodology has been conducted in Argentina, the People's Republic of China, Thailand, Tunisia and the United Kingdom. It involved both discussions with relevant national, LADA, FAO and university personnel to introduce the concept, method, interpretation and field practicality of the VS-Fast methodology as well as one-on-one demonstrations and teaching of the methods in farmers' fields. Field demonstration and testing have been conducted in such cropping lands as rainfed arable lands, olive groves, pasture lands, intensive nursery/orchard enterprises and desert rangelands (low density pastoral).

Strong support has been received at many levels for the need, applicability and relevance of the VS-Fast methodolgy. Most applauded was the 'simple yet robust' nature of the techniques, ensuring immediate data availability while actually standing at the sample site, farmer acceptance and rapid uptake of the descriptive and measurement tools, leading to rapid assessment of the current condition with potential for longer-term monitoring. Positive responses ranged from the policy level, with requirements for regional-level understanding of land conditions — particularly the direction of land condition/health and the potential for improvements with innovative practices, to the farmer level where there was genuine enthusiasm that so much could be learned about soil condition and health in a 20–30 minute field visit.

Future applications of the VS-Fast system are foreseen in several modes. The applicability of the techniques to the assessment of land degradation in the tropical lands of Southeast Asia requires investigation. Additionally, future teaching of the VS-Fast methodology may best be achieved through 'train the trainers' workshops utilizing many facets of the well-established FAO Farmer Field Schools network. With this, the first round of in-country trainees become trainers and impart their knowledge to local farmers/technical staff, thereby achieving wide adoption of land monitoring from individual farm to regional scales. Indicators of soil cover may be introduced to the VS-Fast methodology, an important parameter both in mitigating the impacts of wind and water erosion on the soil surface and demonstrating the application of improved land management in the context of reduced till and the use of cover crops. VS-Fast has potential to be upgraded to a computer-based methodology with screen data entry, automated database facilities and web access, including a 'library' facility of images and data from worldwide sites assessed with VS-Fast. The collected and presented data from the field will remain the core business of VS-Fast but the computer-based system will outreach to another level of interested parties and give a widely available database of successful applications of best practices in land management, duly tested with VS-Fast — akin to and enriching the WOCAT inventory of demonstrated best land management practices.

Soil and water conservation and global use of the Soil and Water Assessment Tool

Soil and water conservation: the World Association of Soil and Water Conservation (WASWC) and its history

The WASWC is an international non-government organization that was established 26 years ago with the objective of promoting the wise use of the earth's land resources. In doing this, it acts as a forum for people from all over the world who are interested in soil and water conservation; it provides us with a network, through which we can make contact with people with similar interests, problems and projects to our own from any country or region in the world; and it provides information — mainly through the quarterly newsletter and monthly HOT NEWS — about matters of mutual interest. The WASWC also sponsors and co-sponsors conferences, seminars and workshops every now and then, and synthesizes and compiles them into book form. Over the last 26 years it has been responsible for producing more than 20 books, which have been made available to members at reasonable prices. Our books have had a major influence on the way soil and water conservation is now perceived and approached in many countries, especially the small booklet, *Land husbandry – a framework for soil and water conservation* — it was one of our first publications and it has been widely distributed and given guidance to many soil and water conservationists in many parts of the world.

The WASWC is run by a hard-working council, who give their time to the association for free. The 25 council members come from different countries all over the world. Being an international group, we represent many regions, countries, interests and experiences. Although the members of the council live in different parts of the world, we are in contact practically every day by e-mail, sometimes several times a day; we conduct nearly all our business and meetings via e-mail.

At present we have approximately 1 000 members from about 100 countries and our membership is growing rapidly. Otherwise, we have around 10 000 guest members.

We also have vice-presidents who represent different countries. It is the responsibility of the vice-presidents to represent the WASWC in their country or region, to advise the president on what is happening and to organize all kinds of activities.

The WASWC works very closely with national soil and water conservation societies, and soil science societies. We have also developed strong links with other related organizations like the International Union of Soil Sciences, the International Erosion Control Association, the International Soil Conservation Organization and the European Society for Soil Conservation.

The Soil and Water Conservation Society and the move to China

When the WASWC was established 26 years ago, we were sponsored and helped by the American Soil and Water Conservation Society, which provided us with a secretariat and ran our affairs from its office in Ankeny, Iowa. It looked after our administration; kept our records, handled our finances and published our books and newsletters. This arrangement worked well for many years but recently there have been difficulties. The main problem was that we had to pay for the services that we received and, being in the United States, it was expensive — in fact, we were beginning to run at a loss and we were using up our small savings.

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We looked at several possibilities and then, in August 2002, we received an offer from the People's Republic of China. The Department of Soil and Water Conservation in the Ministry of Water Resources in Beijing offered to provide the facilities for our secretariat. They offered very generous terms. We have signed an MoU with the Ministry of Water Resources; under this agreement, the Chinese took over responsibilities for the administration of our association from 1 April 2003. We have now cancelled our charity status in the United States and have yet to register with the authorities in China as a non-profit organization.

Vice-presidents

Vice-presidents are appointed by the council; activities of country members can be organized through new or existing organizations, such as national soil and water conservation societies.

We feel that we are conducting a development project, which is more or less a process for establishing a type of movement that is sustainable for a long time. At this point we are certain we have approached the right direction because membership has climbed to more than 1 000 from approximately 100 countries. We are sure there is a major need for a central organization like ours. But the important point is that this kind of organization needs personnel who are willing to work for global soil and water conservationists worldwide, normally without any compensation; those who belong to this category should therefore step forward and unite with our administration in managing the WASWC now and in the future.

WASWC products and services

- Newsletter — in ten languages;
- HOT NEWS and HOT NEWS extra;
- WASWC journal and proceedings;
- *The Land Journal*;
- Special publications — once a year;
- Websites, operated from Guangzhou, Tokyo, Dehra Dun, New Delhi: http://waswc.soil.gd.cn, www.waswc.org;
- Photo websites, operated from Bangkok http://community.webshots.com/user/waswc http://community.webshots.com/user/waswc1;
- Forum for discussion, e.g. law and policy, climate change, monitoring and evaluation (M&E), no till;
- Contacts among professionals in various countries;
- Coordination among various WASWC chapters;
- Supporting conferences worldwide with the 'Cooperation Package';
- Presenting the Norman Hudson Memorial Award annually, plus other awards;
- Coordinating the LANDCON series of meetings, with the use of *Guidelines for successful meetings* developed by the WASWC in 2008.

Some of the main products and services are elaborated on in more detail hereunder:

The Newsletter

I would like to mention the *WASWC newsletter* because its production is probably the most important single component of what we presently do.

For over 20 years the WASWC has produced a newsletter every three months. For a long time this came out as a small printed publication, usually of only four pages. During the time of my predecessor, David Sanders, he and I made a major effort to improve the newsletter by making it longer and to contain more articles that would be of interest and value to our members. When I took up the presidency the council added more pages and sections. A breakthrough came when we were able to produce the electronic newsletter and relay it via e-mail. A former problem had been the difficulty in getting members to contribute articles. This has now changed; we are receiving a wide range of articles, book reviews and other items from all over the world.

The journal/proceedings

Recently the WASWC journal and proceedings have started to publish peer-reviewed articles and non-peer reviewed articles, respectively. Although not published in hard copy they are posted on our website. The WASWC website is going to be used more efficiently for many purposes.

Special publication

It is intended to distribute a special publication to our members for free once a year. We try to find an issue that may attract interest among most of our members in the form of long articles, which can be used as additional reading for students. In 2003 we published *The USLE story* by John Laflen and Bill Moldenhauer. In 2004 we published *Carbon trading – agriculture and poverty* by Mike Robbins. They were followed by *No-till farming systems* and *Soil and Water Assessment Tool (SWAT)*.

The Norman Hudson Memorial Award

The Norman Hudson Memorial Award has been presented to a deserving person since 2004. This is the highest honour bestowed on an individual by the association once a year. It is given for distinguished service in recognition of international accomplishments in soil and water conservation. The award is named after Dr Norman Hudson, whose exemplary professional career was devoted to the cause of global soil and water conservation. To date, Calvin Rose (2004), Rolf Derpsch (2005), John Greenfield (2006), Hans Hurni (2007) and Michael Stocking (2008) have been recipients of the award.

We are not a funding agency

We often get requests that we cannot meet. The WASWC is primarily a professional association of soil and water conservationists. It is not a funding agency. Unfortunately, some of our members do not understand this point and we sometimes receive requests for funding or for help in setting up projects. Of course, we cannot help with these requests other than by putting the people involved in touch with an agency that may be able to help.

The vision and mission statement

The council is very keen that the WASWC should not only grow in membership in various categories, but also that it should become more responsive to the needs of our members. In other words, we want to become more useful to our colleagues. For this reason, we have developed a Vision and Mission Statement, after discussion with members in 2003, which we intend to follow as far as possible.

> ***WASWC Vision:*** *A world in which all soil and water resources are used in a productive, sustainable and ecologically sound manner.*
>
> ***WASWC Mission:*** *To promote worldwide the application of wise soil and water management practices that will improve and safeguard the quality of land and water resources so that they continue to meet the needs of agriculture, society and nature.*

The WASWC slogan

The WASWC slogan, created in 2004, is: *Conserving soil and water worldwide – join WASWC*.

Guidelines for successful meetings and LANDCON meetings

Guidelines for successful meetings is the most recent WASWC tool. We deliberated about it in 2008 and it is in effect now. We did this to assist/support people who organize meetings, so they will successfully obtain good results; it is a way to help academics and professionals know which meetings they should attend, to avoid wasting their time and money. We are proud that the Conference on Land Degradation in Dry Environments in Kuwait has also registered with us as LANDCON 0903 and the outcomes from it will be presented soon on our LANDCON website in India. There are more than ten meetings in the next three years that have registered with LANDCON.

We invite you to write to us to exchange ideas and make your membership creative, and send articles to publish in our newsletter, HOT NEWS or journal/proceedings, so we can continue to function as a forum for soil and water conservationists and academics and professionals in many related fields worldwide.

Soil and Water Assessment Tool: global applications[3]

The Soil and Water Assessment Tool (SWAT) is a river basin- or watershed-scale model developed by Dr Jeff Arnold for the United States Department of Agriculture-Agricultural Research Service (USDA–ARS). SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.

SWAT is a continuation of nearly 30 years of modelling efforts conducted by USDA–ARS. SWAT has gained international acceptance as a robust interdisciplinary watershed modelling tool as evidenced by international SWAT conferences, hundreds of SWAT-related papers presented at numerous other scientific meetings and dozens of articles published in peer-reviewed journals. The model has also been adopted as part of the U.S. Environmental Protection Agency's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) software package and is being used by many American federal and state agencies, including the USDA within the Conservation Effects Assessment Project. At present, over 400 peer-reviewed published articles have been identified that report SWAT applications, reviews of SWAT components and other research that includes SWAT. SWAT has also been used extensively in Europe, including projects supported by various European Commission agencies. Several models including SWAT were used to quantify the impacts of climate change for five different watersheds in Europe and a suite of nine models including SWAT were tested in 17 different European watersheds (Gassman *et al*. 2007). Several countries have developed modified versions of SWAT like SWAT–Korea and SWAT–Germany.

Despite the rise in usage of SWAT, it is mainly used by modellers in developed countries. The expensive cost of computer hardware and licenses for ARC-GIS software has discouraged most developing countries from studying it and made it virtually inaccessible to graduate and undergraduate students of these countries. Fortunately, Chris George from the United Nations University saw the prospects of SWAT. He and his colleagues developed a free open source interface to SWAT, consisting of the GIS system MapWindow and the MapWindow–SWAT interface MWSWAT, which was released on the web in July 2007. However, Internet connectivity is not always dependable and available and SWAT training is needed in many developing nations. Hence, to accelerate the use of SWAT in the developing world, a SWAT textbook has been published and distributed by the WASWC. It is a compilation of several SWAT materials that discuss SWAT fundamentals and MWSWAT; also articles on comprehensive literature review of worldwide SWAT applications, and articles

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[3] This is made possible through support provided by: USDA-ARS, Texas A&M University, United Nations University, Chiang Mai University, Virginia Polytechnic Institute and State University (Virginia Tech), North Carolina Agricultural and Technical State University (NCA&T), WASWC, USAID and the generous support of the American People for the Sustainable Agriculture and Natural Resources Management Collaborative Research Support Programme (SANREM CRSP) under terms of Cooperative Agreement Award No. EPP-A-00-04-00013-00 to the Office of International Research and Development (OIRED) at Virginia Tech, and terms of sub-award agreement 19070A-425632 between Virginia Tech and NCA&T.

on SWAT applications in the United States, Europe, Africa, China, the Middle East, India, Southeast Asia, Republic of Korea and South America. It is also accompanied by a DVD that contains MapWindow, MWSWAT, SWATeditor and SWAT–CUP software with their user manuals as well as other SWAT literature to supplement the SWAT textbook, plus other works of interest in the field of soil and water conservation within the framework of the WASWC.

This textbook was first distributed at the 1st International SWAT–Southeast Asia conference/workshop in Chiang Mai, Thailand,[4] 5–8 January 2009.

[4] See http://www2.mcc.cmu.ac.th/swat/index.php Contact: Dr Attachai Jintrawet at attachai@chiangmai.ac.th, attachaij@gmail.com and Dr Manuel Reyes at mannyreyes@nc.rr.com.

Country Reports

Land degradation assessment in drylands of Cambodia

Abstract

In Cambodia, the major root causes of land degradation are soil erosion, deforestation, seasonal drought caused by inappropriate land use, improper agricultural practices and gemstone mining in the border area between Cambodia and Thailand. High erosion rates occur in the northeastern mountain ranges and high plateau and in the northwestern high plateau — sediment flows into the Tonle Sap Lake via the main tributaries of the Mekong River.

Activities to combat desertification and drought in Cambodia are related to the National Priority Programmes. They cover issues concerning forestry, water resources, biodiversity, natural disasters, climate change, flood and drought prevention and raising public awareness on the environment.

Three factors are commonly cited as causes of desertification: overgrazing, inappropriate agricultural practices and overuse of woody biomass. Such factors are not confined to dry areas and can lead to equally severe degradation in humid areas. Land degradation following mismanagement of the natural resource can occur anywhere, irrespective of the prevailing climatic conditions. For this reason it is believed that the emphasis placed on desertification programmes within the Asia and Pacific region is misdirected. What is needed is a commitment to an holistic approach to land degradation wherever it occurs.

The major causes of land degradation in Cambodia are deforestation by war, unsustainable agricultural and water management practices, land-use changes for development purposes and industrialization. The major process of land degradation is soil erosion due to water and wind erosion. The other processes include waterlogging and salinity–alkalinity. Desertification induces lower agricultural productivity, loss of natural resources (forests and vegetative cover, biodiversity, soil changes) and changes in socio-economic conditions (economic losses, problems of sustainability, decline in quality of life). Desertification is generated by a number of factors including climatic variations and human activities. Anthropogenic causes include expansion of agriculture and unsustainable agricultural practices such as overcultivation, poor irrigation practices, deforestation and overgrazing.

To ensure sustainable forest management, it is important that forest resources, especially the permanent forest estate, are secured and protected from encroachment; also, that they are managed in accordance with best management practices involving the participation of local communities, who are dependent on the forest for their daily subsistence. Reforestation has been developed under the following categories: (1) Economic Land Concession, (2) Forest Land for Tree Planting, (3) Community Forestry Plantation, (4) Government Plantations (including military activities), (5) Individual or Private Plantations and (6) National Arbor Day celebrations with public participation.

To adequately respond to the urgent needs of climate change, in particular droughts and floods, a draft National Adaptation Programme of Action to Climate Change has been prepared containing priority actions needed to adapt to climate change with regard to agriculture, water resource management, coastal zone management and human health.

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The National Poverty Reduction Strategy (2003–2005) recognizes the three aspects of the land management vision — (1) land will be administered so that property rights are legally transparent and secure, (2) concessions will be made to distribute vacant state land to marginalized households for social purposes and (3) land will be managed in an environmentally sustainable way that provides the poor with opportunities to secure access to natural resources (especially land), housing, credit, employment and investment.

1. Overview

Cambodia is located in the peninsula of mainland Southeast Asia with a land area 181 035 km^2. It is adjacent to the Gulf of Thailand and has a coastline of approximately 435 kilometres. Its land border of 2 438 kilometres extends along Thailand to the west, Viet Nam to the east and Lao PDR to the north.

Environmentally, economically and even culturally, Cambodia is dominated by the Tonle Sap, the largest freshwater lake in Southeast Asia, and associated Mekong lowlands. In the rainy season the Mekong River backs up and flows into the Tonle Sap, causing the lake to swell to four times its normal size.

The country is dominated by three mountainous regions in the southwest, north and northeast, which are less populated and rich in forest resources. Forest types range from tropical moist forest in the southwest Cardamom Mountains to dry mixed deciduous forest in the north and east, as well as remnants of flooded forest around Tonle Sap Lake.

Cambodia's climate is governed by monsoons and is characterized by two distinct seasons: from mid-May to early October, strong prevailing winds from the southwest bring heavy rains and high humidity, and from early November to mid-March winds and humidity are low. Between these seasons is a transitional period. The rainfall pattern changes with elevation. The average annual rainfall is 1 400 mm in the central lowland regions and may reach 5 000 mm in certain coastal zones or in highland areas.

The population of Cambodia is estimated at 13.8 million with an annual growth rate of approximately 2.5 percent (projected from the General Population Census of Cambodia 1998). Fifty-two percent of the population is female. About 84 percent of the population lives in rural areas. Cambodia's urban population (16 percent of the total) is principally located in two centres, one of them being Phnom Penh, with an estimated population of 1 million and an annual growth rate of 3.5 percent.

Population density varies widely across the country, with a national average of 76 persons/km^2. Six provinces located in the central plain and around the capital account for close to 60 percent of the total population, Battambang and Benteay Meanchey Provinces, bordering Thailand in the west, account for a further 10 percent and Svay Riang Province, bordering Viet Nam in the southeast, for another 5 percent. In contrast, other provinces, in particular Rattanakiri and Mondulkiri in the northeast, are very sparsely populated (about 1 percent of the total population).

About 90 percent of the soils in Cambodia are chemically degraded, generally acidic, sandy and have poor soil fertility. Map 1 shows the status of soil fertility and productivity in the country. These soils — classified as Latosols, Acrisols and Ferrasols — are associated with thin surfaces and low organic matter as they have depleted calcium and magnesium content.

Land degradation in Cambodia is a serious threat to national food security as most of the population is poor and has limited financial capacity to augment its food supply. Land degradation is generated by both human-induced and natural causes. Soil erosion and loss of soil fertility are forms of land degradation. Researchers have indicated that in areas with active rill erosion, crop yield is reduced by 20 to 25 percent in the second year of cultivation and by 40 to 50 percent in the fourth year.

Land degradation caused by deforestation and improper agricultural practices has very serious effects on agricultural productivity and the livelihoods of marginalized communities, regeneration of natural forest species, soil water retention capacity and natural habitat regeneration.

2. Land

A well-defined land management technique is critical to socio-economic development as 85 percent of the population relies on a fragile balance of agriculture, fisheries and forest products for survival. Out of Cambodia's total land area, 54.1 percent is forested, 23.4 percent is used for agriculture, 6.8 percent is wetlands, 15.6 percent is woodland and grasslands and 0.1 percent is used for settlement (JICA 2002). Cambodian agriculture is predominantly organized on the basis of small farmer communities. The plight of these communities relative to access to natural resources and landownership is possibly one of the most significant factors facing land-use issues today.

A statement on land policy was issued in 2001. Its objectives are to (i) strengthen land tenure, security and land markets, and prevent or resolve land disputes; (ii) manage land and natural resources in an equitable, sustainable and efficient manner; and (iii) promote land distribution in an equitable manner.

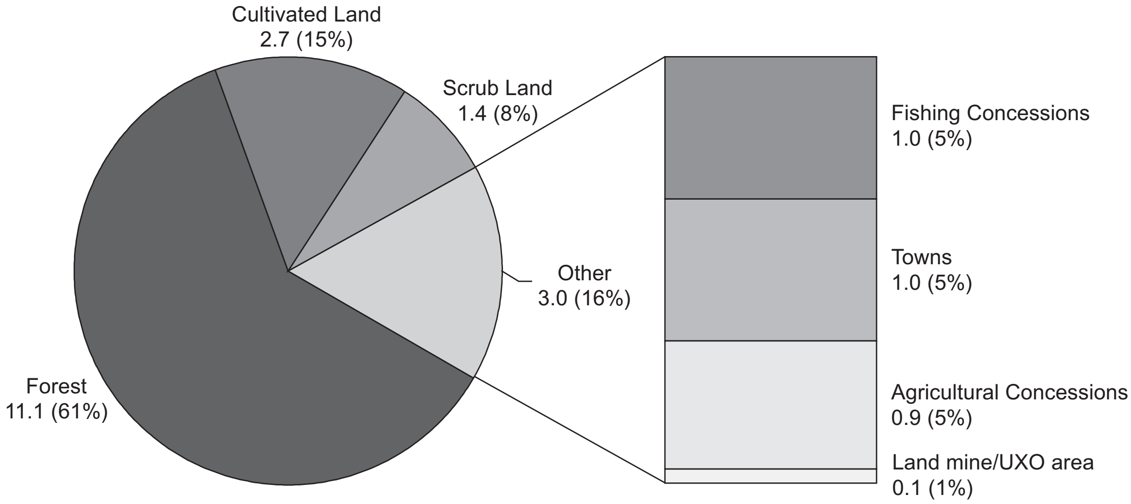
Over the last decade, the main form of land use and management has been the establishment of industrial concessions in the forestry, fisheries and more recently, in the agricultural sectors. The unsustainable use of many of these concessions, combined with their inability to increase economic activity at the local level, has led the Royal Government of Cambodia (RGC) to seek alternative management practices that will support its goal of poverty alleviation combined with increased environmental sustainability.

Table 1. Land-use types in Cambodia (in hectares)

Land-use type	Area	Land-use type	Area
Rice fields	3 163 000	Woodland and scattered trees	1 266 100
Field crops	372 600	Shrubland	1 094 000
Swidden agriculture	349 700	Grassland	861 600
Village garden crops	198 300	Flooded shrubland	533 200
Receding rice & floating rice fields	194 000	Flooded grassland	173 500
Rubber plantations	88 300	Barren land	27 200
Urban and built-up areas	18 100	Sand terrain	7 500
Orchards	8 800	Rocky outcrops	1 800
Salt pans	6 100	Perennial waterbodies	91 100
Evergreen broadleaf forest	3 922 638	Mangroves	64 900
Deciduous forest	3 549 993	Marsh or swamp	44 600
Mixed forest of evergreen and deciduous species	1 429 007	Flooded forest	20 600

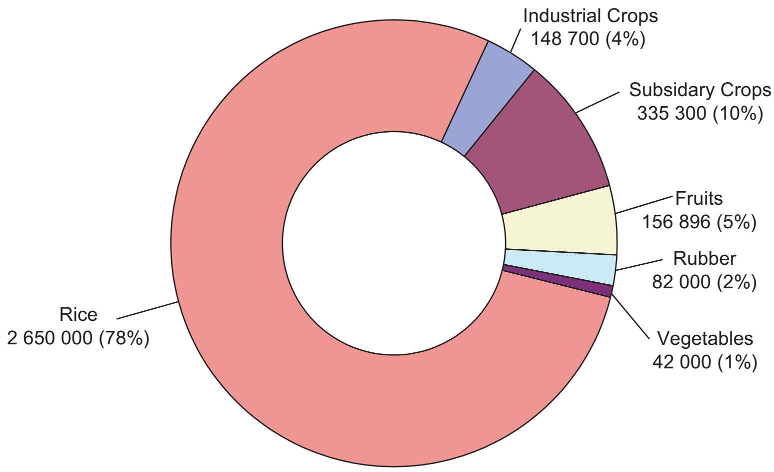
Sources: JICA 2002; International and Provincial Boundary: Department of Geography 2005.

Fertile land is mostly used for producing rice. Other non-rice land is used for maize, mung bean, soybean, cassava and sugar cane. Rubber is also an important crop in eastern Cambodia. Cultivated agricultural land is estimated at around 3.5 million hectares out of total agricultural area of approximately 4.1 million hectares.



Source: DANIDA (2006).

Figure 1. Land use in Cambodia



Source: MAFF (2008).

Figure 2. Cultivated agricultural land use: 3.5 million hectares (2007)

3. Cambodia's forest cover resource

In 1965 forests covered an estimated 73 percent of the country's territory. To monitor the loss of forest land, the Forestry Administration conducted a series of forest cover assessments in 1992/1993, 1996/1997, 2000 (partial) and 2002. Results showed that Cambodia's forest cover had declined to an estimated 61 percent of the total land area in 2002. The loss of forest cover is consistent with land-use and land cover change patterns associated with demographic growth and economic development in most countries.

Insecure titles over land and unclear land-use rights continue to critically hamper the efforts of Cambodia's rural poor to secure their livelihoods. Agricultural expansion, illegal logging, a construction boom and increasing demands for land associated with growth in Foreign Direct Investment from Southeast Asia continue to result in the loss of forests, and the increased vulnerability of communities who depend on forest resources. There is clearly a need to ensure sustainable management and equitable use of forests, to improve rural livelihoods and to promote balanced socio-economic development in Cambodia.

3.1 Forest Cover Resource Assessment 2006

The 10th meeting of the Technical Working Group on Forestry and Environment held on 26 September 2006 agreed to support a national forest cover change assessment for 2005/2006 with financial assistance provided by the Royal Danish Embassy–DANIDA, Phnom Penh. The Geographic Information System and Remote Sensing (GIS-RS) Unit within the Forestry Administration's Watershed Management and Forest Land Office conducted the forest cover change assessment using Landsat ETM+data. Independent quality assurance and data verification were carried out by Geographic Resource Analysis and Science (GRAS A/S) at the Geocenter, University of Copenhagen. The resulting forest cover statistics for 2006 are shown in Table 3.

Table 2. Landsat satellite images

No.	Path/row	Date of acquisition
1	125/50	9 March 2005
2	126/51	11 January 2005
3	127/50	23 March 2005
4	127/51	7 March 2005
5	127/52	7 March 2005
6	128/51	26 February 2005
7	124/51	21 March 2006
8	TM 124/52	22 February 2005
9	125/51	8 February 2006
10	125/52	24 February 2006
11	126/50	11 January 2005
12	126/52	16 March 2005
	TM 126/52	3 January 2005
13	126/53	12 February 2005
14	127/53	2 January 2005
15	128/50	12 January 2006

Source: Forest Cover Statistics (2006).

Table 3. Forest cover statistics, 2006

No	Forest types	Area	
		Hectares	%
1	Evergreen forest	3 668 902	20.20
2	Semi-evergreen forest	1 362 638	7.50
3	Deciduous forest	4 692 098	25.84
4	Other forest	1 007 143	5.55
	Total forest land	**10 730 781**	**59.09**
5	Non-forest	7 429 893	40.91
	Total area	**18 160 674**	**100**

3.2 Forest cover change from 1965 to 2006

The forest cover area in 1965 was 73.04 percent of the total land area and this declined to 59.09 percent in 1993 and 58.60 percent in 1997. In 2002, the forest area was 61.15 percent and this decreased to 59.09 percent in 2006 (Table 4).

Therefore, Cambodia's forest cover change from 1965 to 2006 was 13.95 percent or 0.34 percent per year.

Table 4. Cambodia forest cover estimates, 1965–2006

Assessment by year	Land				Total area (ha)
	Forest land		Non-forest land		
	Hectares	%	Hectares	%	
1965	13 227 100	73.04	4 883 400	26.96	18 110 500
1992/1993	10 859 695	59.82	7 293 290	40.18	18 152 985
1996/1997	10 638 209	58.60	7 514 776	41.40	18 152 985
2002	11 104 293	61.15	7 056 383	38.85	18 160 677
2006	10 730 781	59.09	7 429 893	40.91	18 160 674

4. Wetlands

Most of Cambodia's freshwater wetlands are found around the Tonle Sap Lake and along the Mekong River and its tributaries. They comprise the Tonle Sap Lake, other permanent lakes and swamps and annually inundated floodplains. The total wetland area increases nearly tenfold from about 0.5 million hectares in the dry season to 5 million hectares in the wet season (July to September) in an average year. The Tonle Sap Lake alone increases fourfold in area from 250 000 hectares in the dry season to about 1 million hectares in an average year, and to about 1 350 000 hectares in a wet (heavy rain) year. The surface of the lake was reported to expand from 2 700 km^2 during the dry season to approximately 16 000 km^2 at the maximum level of flooding; the water level depths vary between 1 metre in the dry season to 9 metres in the wet season (Guiscafre 1963). The total wetland area in an average year represents nearly 28 percent of the total area of the country and in a wet year it could be as high as 35 percent.

5. Rivers and lakes

Worldwide, freshwater habitats are very limited in area, with inland lakes covering about 1.8 percent of the Earth's surface and running water in rivers and stream covering about 0.3 percent.

The Mekong River–Tonle Sap system dominates the hydrology of Cambodia. The Mekong River rises in the Tanghla Shan Mountains in the Tibetan Plateau and flows through Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam. A further 10 to 20 percent comes from the Sesan, Srepok and Sekong Rivers in northeast Cambodia and the remaining 10 percent from the rivers that drain into the Tonle Sap Lake (Pantulu 1986). Eighty-six percent of Cambodia lies within the catchment of the Mekong River.

Environmentally, economically and even culturally, Cambodia is dominated by the Tonle Sap, the largest freshwater lake in Southeast Asia, and associated Mekong lowlands. An unusual phenomenon occurs in the rainy season when the Mekong River backs up and actually flows into the Tonle Sap, causing the lake to swell up to four times its normal size. Consequently, the Tonle Sap and surrounding lands are unusually productive, both for agriculture and fisheries. It is the wealth generated from this productivity that was a major factor leading to the emergence of the Angkorian Empire, which dominated Southeast Asia from the ninth to the fourteenth centuries, CE.

6. Soil erosion and sedimentation reduction

6.1 Soil erosion

In the soil conservation arena the terms soil degradation and land degradation are sometimes used interchangeably, with 'soil erosion' being synonymous to both terms. However there is more to soil degradation than just soil erosion, and land represents a broader concept than simply soil. As to its use in the context of land evaluation (FAO 1976a), the term 'land' refers to all natural resources that contribute to agricultural production, including livestock production and forestry. Land thus covers climate, landforms, water resources, soils and vegetation (including both grassland and forests).

Combating soil degradation or desertification cannot be addressed in isolation from other natural resources, as degradation of one can be expected to have an adverse impact on the agricultural productive capacity of the others.

Three factors are commonly cited as causes of desertification: overgrazing, inappropriate agricultural practices and overuse of woody biomass. Such factors are not confined to dry areas and can lead to equally severe degradation in humid areas. Land degradation following mismanagement of natural resources can occur anywhere, irrespective of the prevailing climatic conditions. For this reason it is believed that the emphasis placed on desertification programmes within the Asia and Pacific region is misdirected. What is needed is commitment to an holistic approach to land degradation wherever it might occur.

In Cambodia, soil erosion is a threat in some regions throughout the country, in particular to terrain and steeply sloping areas where heavy logging activities are being carried out, for example in the northeast (Mondulkiri, Kratie, Steoung Treng and Ratanakiri Provinces) and the southwest (Kompot and Kompaong Speu Provinces).

6.2 Wind erosion

The risk of wind erosion is severe in the arid and semi-arid areas of Asia and Australia. It includes both the removal and deposition of soil particles by wind action and the abrasive effects of moving particles as they are transported. It occurs when soil is left bare of vegetation as a result of cultivation, and/or overgrazing following overstocking. Not only can the wind remove topsoil from good farmland, it can also result in additional damage by burying land, buildings, machinery and fences with unwanted soil. There are no data recorded with regard to deposition of soil particles in the valleys or plains in Cambodia. However, it is estimated that in Pakistan some 42 percent of the arable land is affected by wind erosion, and in India the corresponding figure is 6 percent, with the same total affected area of 11 million hectares as for Pakistan (FAO 1994a). In China there are reports that windblown sand has affected some 2.65 million hectares of cultivated land (ESCAP 1995).

6.3 Water erosion

Water erosion is the most widespread form of degradation within the Asia and Pacific region and occurs widely in all agroclimatic zones. This category includes processes such as splash erosion, sheet erosion, rill and gully erosion and mass movement (Douglas 1994):

- Splash erosion commonly initiates water erosion and occurs when raindrops fall onto the bare soil surface. The impact of raindrops breaks up the surface soil aggregates and splashes particles into the air. On sloping land relatively more of these particles will fall down-slope, resulting in a net downhill soil movement. Some of the soil particles may fall into the voids between the surface aggregates and thereby reduce the amount of rainwater that can infiltrate the soil and increase runoff.
- Water running over the soil surface has the power to pick up some of the particles released by splash erosion. It can also detach particles from the soil surface. This may result in **sheet erosion** where soil particles are removed from the whole soil surface on a fairly uniform basis. Where runoff becomes concentrated into channels **rill and gully erosion** may result. Rills are small rivulets of such a size that they can be worked over with farm machinery. Gullies are much deeper (often being several metres in depth and width) and form a physical impediment to the movement, across the slope, of farm machinery.
- On sloping land when soil is saturated, the weight of the soil may exceed the force holding the soil in place. Under such circumstances **mass movement** in the form of landslides or mudflows may occur. On steep slopes this mass movement may be very rapid, involving the movement of large volumes of soil, usually in an isolated event and localized basis. In terms of Cambodia the areas prone to mass movement are located along the steep slopes of the Mekong, Tonle Sap and Prasac Rivers. These landslides are associated with natural weather phenomena and strong water flow.

6.4 Sediment reduction

Erosion results in sedimentation, which can have positive effects, such as fertilizing the soils, and negative effects such as making a lake shallower.

Only one study of the sedimentology of the Tonle Sap Lake area has been made; it was conducted in 1962 to 1963 (Carbonnel and Guiscafré 1963). The researchers drilled 19 holes in the dry season lake bottom and concluded that the lake was formed about 5 000 years ago by a transgression of the sea (sea-level rise) and had been depositing at a rate of 0.3 mm/year since then.

7. Root cause of land degradation

In Cambodia, the major root causes of land degradation are soil erosion, deforestation, seasonal drought caused by inappropriate land use, improper agricultural activities and gemstone mining in the border area between Cambodia and Thailand. High erosion rates occur in the northeastern mountain ranges and high plateau and in the northwestern high plateau — sediment flows into the Tonle Sap Lake via the main tributaries of the Mekong River.

Illegal mining activities have been the major cause of sedimentation in the Tonle Sap Basin and siltation in the rivers, especially in the Tonle Sap Great Lake. In the 1960s the sedimentation rate was recorded at 2 cm/year (FAO 1991). Increased sedimentation rates of the lake are attributed to deforestation in the upper reaches of the Tonle Sap Watershed and the flooded forest, gemstone mining in Pailin City and increase in the Mekong’s silt load due to deforestation in other parts of the Mekong Basin.

Besides sedimentation of the lake, soil erosion in the mountain ranges also causes some estuaries along the coast to become shallower year after year. However, a sedimentation survey in the rivers along the coast has never been conducted.

In discussing land degradation, as a general phenomenon, the National Action Programme for Sustainable Land Management (NAP) identified its impacts as covering loss of land productivity, loss of ground cover, loss of biodiversity, loss of livelihoods and poverty exacerbation.

Looking more specifically at soil degradation, the NAP distinguishes between natural degradation, caused by leaching of bases, resulting in increased acidification and a reduction in productivity, and human-induced soil degradation. This latter phenomenon results in soil erosion, rapid depletion of organic matter, loss of effective soil depth for root development and deterioration of plant vigour. It occurs due to factors such as declining fallow periods, overirrigation, inappropriate use of herbicides and other chemicals and burning of agricultural residues.

The underlying causes are related to continued uncertainty over access to land and land tenure, compounded by postconflict population growth, resulting in migration of farmers into marginal lands and into environments to which their knowledge and agricultural techniques are not well adapted.

8. Natural disasters

8.1 Flooding

Cambodia experiences flooding every year during the August–November monsoon, the extent of which varies from year to year, but the area of inundated land is normally in the region of up to 4 million hectares (Nedeco 1998). The most densely settled part of Cambodia is on the floodplain of the Mekong, Tonle Sap and Tonle Bassac Rivers. For millions of people living in these regions, the annual floods are a vital part of their livelihoods, providing a wealth of biodiversity and increased soil fertility in the basin. Occasional extreme flooding however, such as that experienced in 2000, poses a risk to communities and causes a great deal of damage to property.

The flooding experienced in 2000 affected almost all provinces in Cambodia (Chan *et al*. 2001). The death toll was reported to be 347, of whom 80 percent were children. Over 3.4 million people had to be evacuated from their homes and the government estimated the cost of physical damage to be US$161 million (MRC 2003a). These figures demonstrate the devastating impact that flooding can have in Cambodia on food security. In addition, damage to roads and bridges often cannot be repaired quickly, which increases transport costs and impedes social development.

The natural cause of flooding is an increase in rainfall and runoff over saturated soil. However, it can result from human influences including induced climate change, deforestation, land degradation and changes in flood storage capacity and other development such as land-filling for urbanization (MRC 2003a).

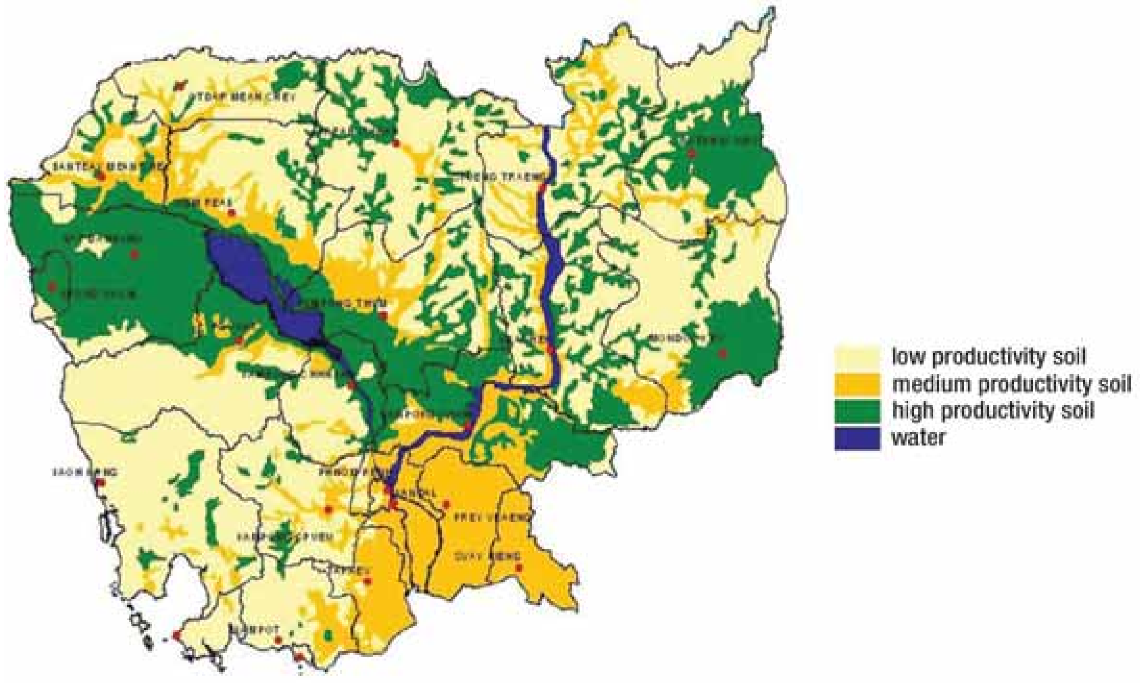
The Mekong River Commission (MRC) and the Ministry of Water Resources and Meteorology (MOWRAM) provide a flood warning service based on real-time transmission of observations at nine stations and a Flood Forecasting Model. Forecasts for the Mekong mainstream are provided by the MRC to the Cambodia National Mekong Committee, Cambodia National Committee for Disaster Management, RGC ministries and the public via the Internet and news media. Whilst these improved warning systems may help to mitigate the effects of flooding, they are unfortunately not able to completely safeguard those in affected areas, and also because postflood hardship among the rural poor is more severe than the flood itself (CARE 2002).

The policy elements for disaster reduction caused by flooding are:

- Promote and pay attention to the study and construction of protective dams along with canals to minimize natural disasters caused by water;
- Implement all relevant measures to reduce the flooding in affected areas;
- Immediate response to those areas that are affected by drought and flooding, and the disaster caused by water inundation;
- Continue to provide incentives and promote citizens and institutions to participate in the process of disaster reduction by preparing safe hilly refuges together with the supply of necessary equipment, machinery, training and demonstration of new technologies that respond to the actual situation; and
- Participate actively in national, regional and international programmes for reduction of the adverse impacts caused by water inundation.

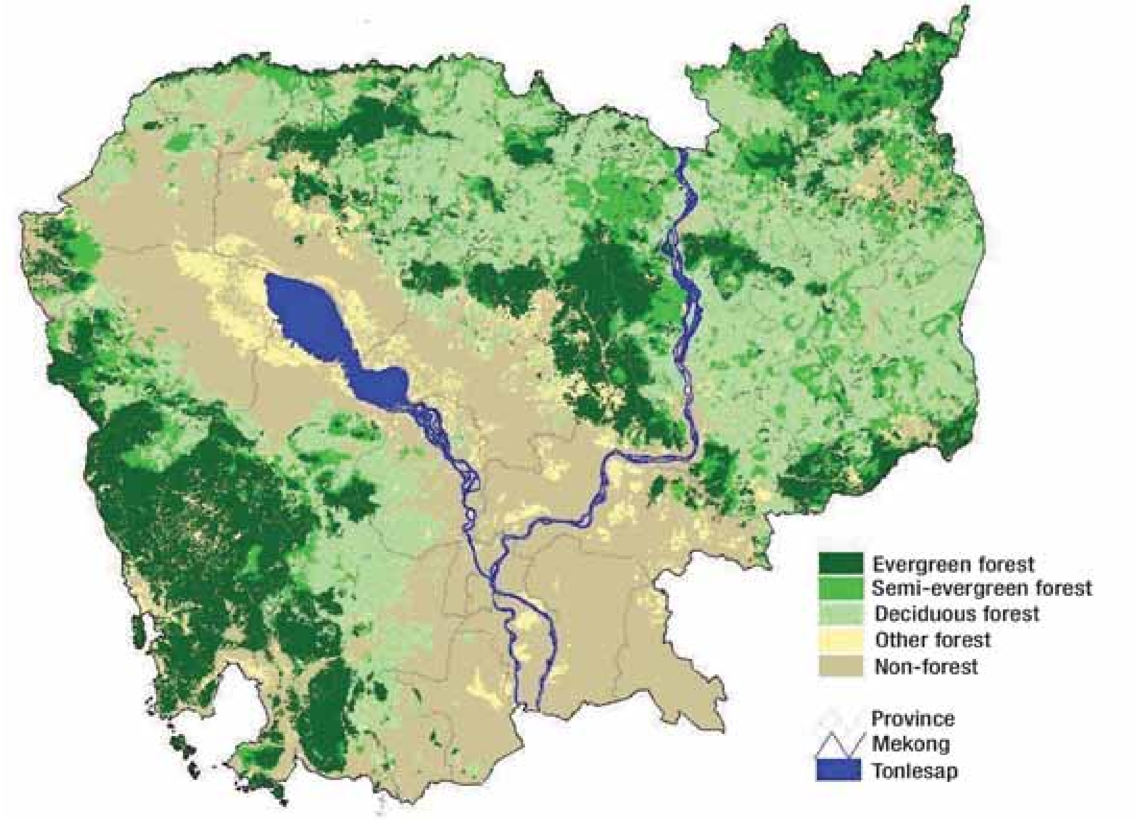
8.2 Drought

- Drought is a problem in parts of Cambodia during the rainy season with some effects during the dry season too, although not to the same extent as seen in countries along the Mekong River. Cambodia in general is rich in water resources; however, some areas also face water shortage. Cambodia's groundwater resources are estimated to be more than one thousand times the current demand (MOWRAM 2000). The extent of drought varies from year to year, as with flooding, with the impact being more pronounced in some years than in others. In 2002, for example, Cambodia experienced both drought during the dry season, and extreme flooding during the monsoon, however the impact of the drought was estimated to be more widespread than that of the flooding (MRC 2003a).
- Drought causes hardship in terms of reduced access to safe drinking water and threatens food security due to lack of water available for agriculture and fishing. In the particularly bad drought year of 1994, crop losses reached as high as 54 percent in Battambang Province (MOWRAM 2000). Reduced rainfall early on in the rainy season can affect land preparation and planting, and later on in July and August can affect transplanting of rice and cause poor growth. In addition, low water levels in rivers lead to a smaller area of land available for use for recession rice growth as flood waters recede (Mckenney and Tola 2002). Drought may be caused by insufficient rainwater storage or absorption for use in the dry season.



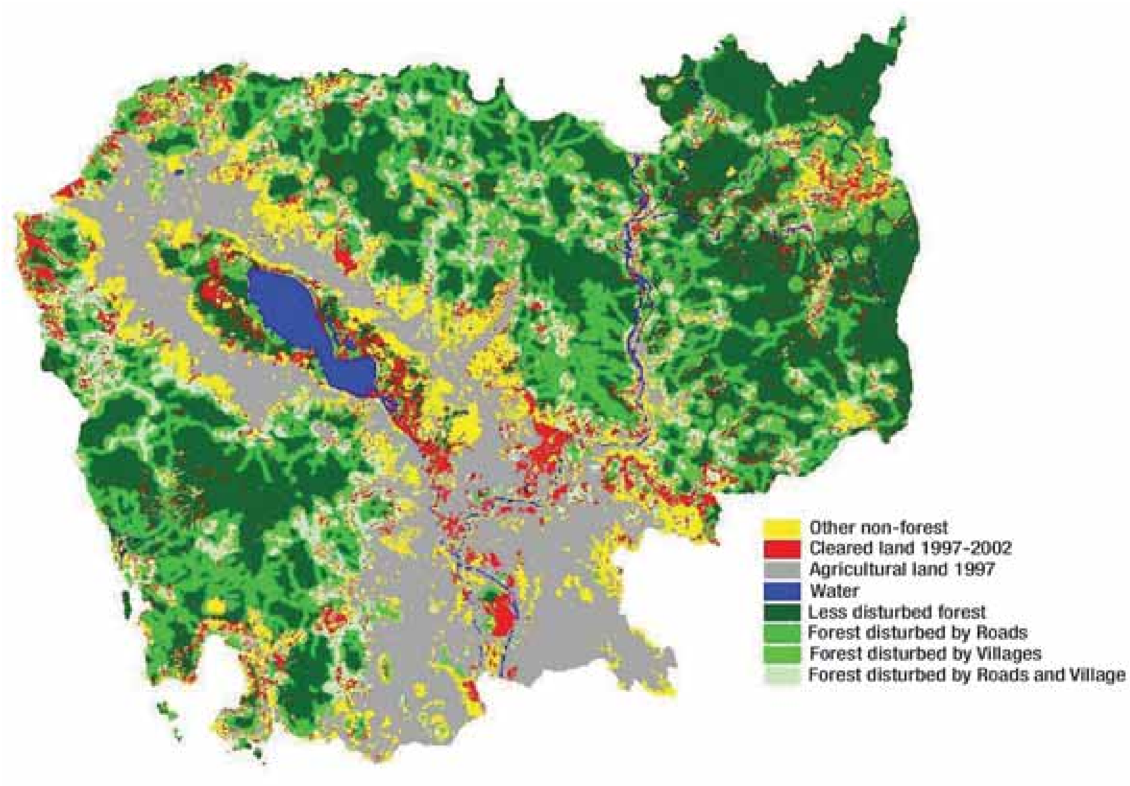
Source: FA/CTSP (2003), Gene-Ecological Zonation of Cambodia
Forestry Administration/Cambodia Tree Seed Project/DANIDA (2005)

Map 1. Generalized distribution of soil fertility classes



Source: Independent Forest Sector Review Team (2004)

Map 2. Forest cover (2002)



Source: Independent Forest Sector Review Team (2004).

Map 3. Level of disturbance

Conclusion

The major causes of land degradation in Cambodia are deforestation by war, unsustainable agricultural and water management practices as well as land-use changes for agricultural development purposes and industrialization.

To address land degradation issues, further international backstopping and networking are needed. Scientific and organizational guidance is also required, including technological support and information. Long-term leadership should promote greater participation among the stakeholders involved.

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Land degradation assessment in the arid areas of China

Abstract

The People's Republic of China has a widely distributed area of highly desertified land. The gravity of land desertification has threatened China's ecological security and sustainable socio-economic development as well as the subsistence and development of the nation. In order to master the status quo and dynamic changes of desertified land nationwide, to provide scientific support and databases for macro decision-making by the central government and to implement the UNCCD, the State Forestry Administration has completed three rounds of National Monitoring Surveys for Desertification since 1994. The findings of the surveys provide support for the decision-making process for ecological development and combating desertification. The results of the desertification surveys showed that through the implementation of the forestry development strategy with ecological development as a priority, the expansion of desertification in China has been primarily brought under control and the 'Stalemate of Ecological Management and Destruction' has been realized.

1. Land degradation situation in arid areas of China

1.1 Scope of arid areas in China

According to the United Nations Convention to Combat Desertification (UNCCD), 'arid areas' refer to the arid, semi-arid and arid sub-humid lands that are classified by aridity indexes (0.05–0.65). China's arid areas are mainly distributed in most of the northwest region, north of North China, west of Northeast China and in the Northern Tibetan Plateau. In terms of administrative division, the areas include 13 provinces (municipalities, autonomous regions). Following the indicators set by the UNCCD, the area of arid, semi-arid and arid sub-humid land in China amounts to 3.317 million km^2 (not including the extremely arid areas, which cover 0.253 million km^2), accounting for 34.6 percent of the total territory. If the extremely arid areas were included, the total arid area would be 3.57 million km^2, accounting for 37.24 percent of the total territory.

1.2 Desertification and land degradation

'Desertification' refers to *land degradation in arid, semi-arid and arid sub-humid areas resulting from various factors, including climatic variations and human activities* according to the UNCCD definition. In FAO documents, the term 'dryland' usually encompasses the area descriptors in the UNCCD definition. Therefore, the term 'dryland' to be used in this report mirrors arid, semi-arid and arid sub-humid areas, subsequently simplified as arid area as found in the UNCCD text. Likewise, 'land degradation' in arid areas corresponds to 'desertification' in this document.

1.3 Desertification situation in China

Land experiencing desertification nationwide in 2004 amounted to 2.6362 million km^2, or 27.46 percent of the total territory, in 498 counties (banners and county-level municipalities) of 18 provinces (autonomous regions, municipalities directly under the leadership of the central government).

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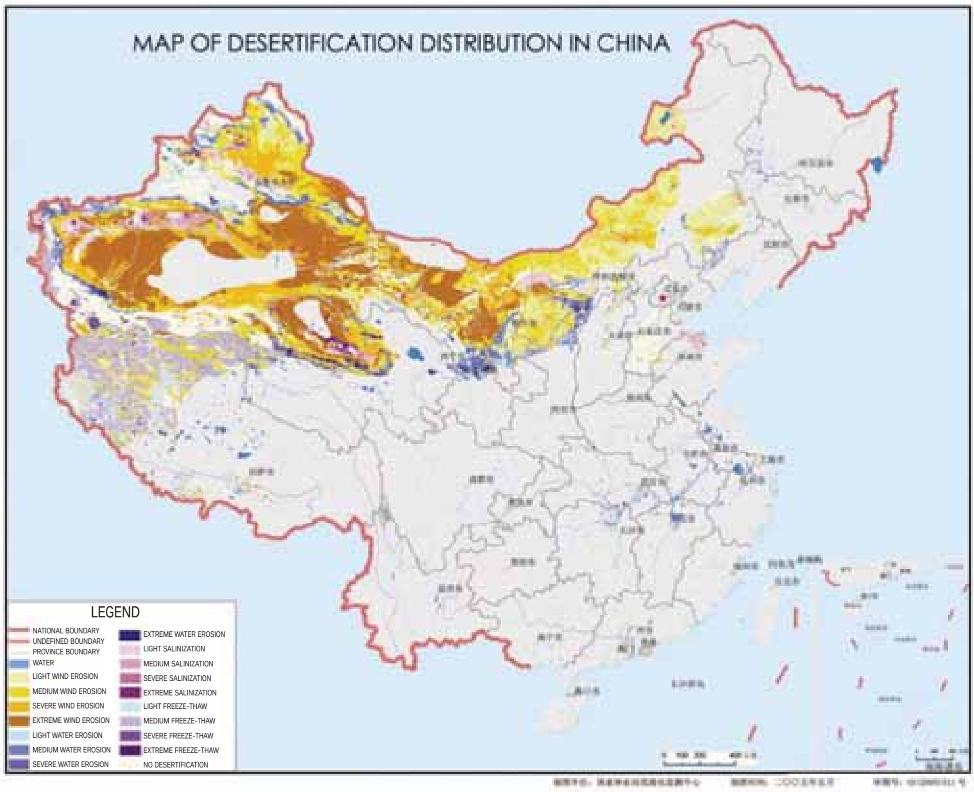

Figure 1. China desertification distribution map

Desertified land in arid, semi-arid and sub-humid arid regions amounts to 115 million, 971 800 and 514 400 km^2 equivalent to 43.62, 36.86 and 19.52 percent of the total desertified land area, respectively.

Wind-eroded desertification, water-eroded desertification, salinization and freeze-thaw desertification cover 1.8394 million, 259 300, 173 800 and 363 700 km^2 accounting for 69.77, 9.84, 6.59 and 13.80 percent of the total desertified land area, respectively.

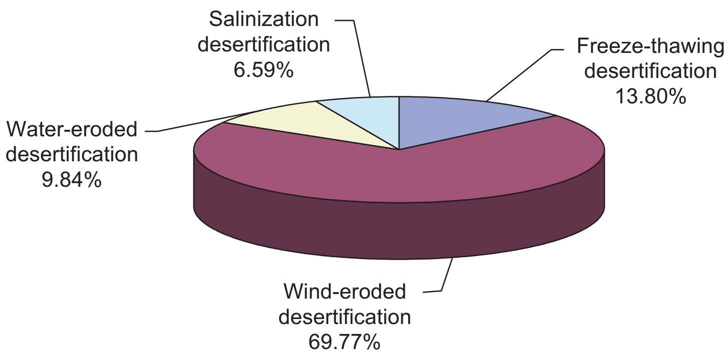

Figure 2. Distribution of desertified land types

Lightly desertified land, moderately desertified land, severely desertified land and extremely desertified land respectively cover 631 100, 985 300, 433 400 and 586 400 km^2 equivalent to 23.94, 37.38, 16.44 and 22.24 percent of the total desertified land area, respectively.

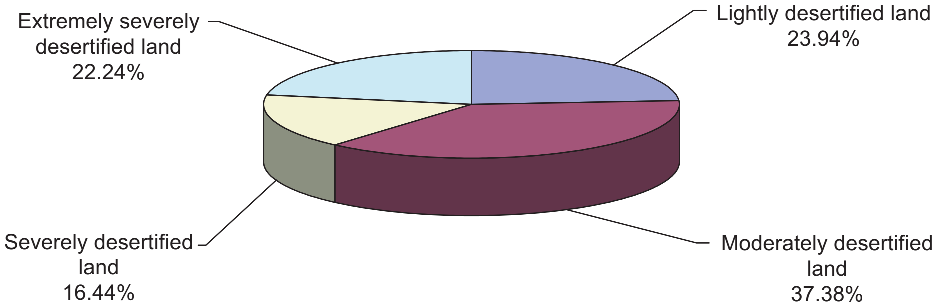

Figure 3. Distribution of desertified land at various degrees

1.4 Change dynamics of desertification

Compared to 1999 data, the total area of desertification in China has declined by 37 924 km^2. Also, the wind-eroded area has declined by 33 673 km^2 and the water-eroded area by 5 525 km^2. Similarly the lightly affected and moderately affected areas have increased by 90 700 km^2 and 117 300 km^2 respectively; severely and extremely affected areas have decreased by 131 800 km^2 and 114 200 km^2 respectively.

1.4.1 Change dynamics of desertified land

Before the 1990s, desertification in China was intensifying and desertified land was increasing by 10.4 thousand km^2 each year. But the situation has reversed since 1999; in 2004, the national desertified land area had decreased by 33 673 km^2, representing an annual reduction of 7 585 km^2.

(1) Change dynamics in terms of different desertification types: Compared with 1999 data, the area of desertified land generated by wind and water erosion had decreased by 33 673 km^2 and 5 525 km^2 respectively, while that of desertified land caused by salinization had increased by 930 km^2.

(2) Changes dynamics in terms of desertification degree: Compared with 1999 data, the area of lightly and moderately desertified land had increased by 907 000 km^2 and 117 300 km^2 respectively, while that of severely and extremely desertified land had decreased by 131 700 km^2 and 114 200 km^2 respectively. This means that the overall degree of desertified land is decreasing.

(3) Change dynamics of desertification in major provinces (autonomous regions, municipalities directly under the central government): Compared with 1999 data, the area of desertified land in 16 provinces (autonomous regions, municipalities directly under the central government) has decreased; for example decline in Inner Mongolia, Xinjiang, Hebei, Ningxia, Gansu, Shaanxi, Liaoning, Jilin and Shanxi by 16 059, 14 226, 4 029, 2 329, 1 900, 1 257, 772, 231 and 149 km^2 respectively.

1.4.2 Change dynamics of sandified land

The sandification situation is very similar to that of desertification. In the 1960s it was expanding by 1 560 km^2 per year, in the 1970s by 2 100 km^2 per year, in the 1980s by 2 460 km^2 per year and in the 1990s by 3 436 km^2 per year; but at the beginning of the twenty-first century sandified land had declined by 1 283 km^2.

For the period 1999–2004, national sandified land area had a net decrease of 6 416 km^2, with an annual reduction of 1 283 km^2.

(1) Change dynamics of sandified land in terms of different types: Compared with 1999 data, the area of shifting and semi-fixed sand dunes (sandy land) had diminished by 15 651 and 23 098 km^2 respectively, while that of fixed sand dunes (sandy land) had increased by 33 265 km^2.

(2) Change dynamics of sandified land in major provinces and autonomous regions. Compared with 1999 data, the area of sandified land in 27 provinces (autonomous regions, municipalities) had decreased; for example in Inner Mongolia, Hebei, Gansu, Shanxi, Shandong, Sichuan, Ningxia, Jiangsu and Shaanxi by 4 882, 959, 836, 782, 380, 375, 254, 227 and 208 km^2 respectively.

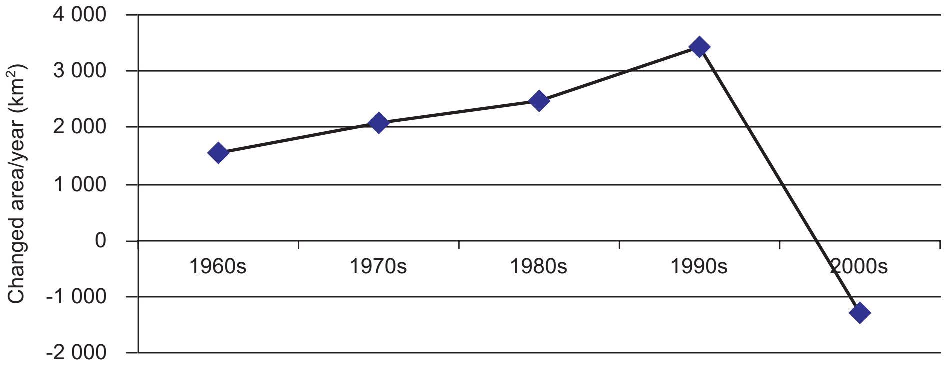

Figure 4. Change dynamics of sandified land

1.4.3 Major regions with dynamic desertification and sandification changes

Compared with 1999 data, regions with dynamic desertification and sandification changes can be classified into four categories:

1. Where the situation is continuously improving, including Horqin sandy land, Ningxia Plain, the southern edge of Mu Us sandy land — characterized by gradually diminishing sandified area, increased vegetation and improved ecological conditions.
2. Where desertification and sandification were once expanding but now are showing reverse effects, including Otindag sandy land and the Bashang region of Hebei. Through the implementation of the Desertification Combating Programme in Wind/Sand Source Areas Affecting Beijing and Tianjin, sandification expansion of these two areas has been contained, vegetation has been rehabilitated markedly and the ecological situation has significantly improved.
3. Where desertification and sandification had been expanding dramatically and are now decelerating, including the lower reaches of the Tarim and Heihe Rivers. Through water delivery and water treatment, which is urgently warranted, the vegetation in parts of the two areas has begun to recover; vegetation degradation and oasis shrinkage have been mitigated to a certain extent, although there is still much to be done before complete rehabilitation is achieved.
4. Where desertification and sandification were expanding and are still expanding, including Minqin Oasis of Gansu, the headwaters of the Three Major Rivers and Shouqu area of the Yellow River. Owing to the impacts of improper use of resources and drought, the sandified land in these areas is still expanding and the ecological situation is deteriorating further.

2. Cause and effect analysis of desertification in China

The two main factors that cause desertification are natural causes and human activities.

2.1 Natural causes

There are two main aspects in this context: The first is the fragile natural climate and geological history that fostered desertification; for example drought and prevailing winds are fundamental preconditions for desertification to occur. The second is the current climate variation and unforeseen climatic events that directly result in desertification such as desert expansion generated by high winds, sandification of arable land and the impact of sand storms. China's arid zone has become the driest area with the least precipitation, the highest evapotranspiration, strong winds and a highly fragile ecological environment. The extremely fragile ecological environment is highly sensitive to changes in external conditions and has a lower coefficient of flexibility, which means poor capacity to recover after a natural catastrophe, i.e. it is easy to destroy and difficult to rehabilitate.

2.2 Human activities

Anthropogenic effects on desertification are mainly related to rigorous natural conditions. The formation and processes of desertification can be controlled or reversed if humans harmonize relations with nature and utilize dryland natural resources properly. However the opposite occurs if natural resources are abused, examples of which are given hereunder.

▲ *Overgrazing*

Overgrazing is the leading factor in rangeland degradation. At present, the actual animal population exceeds the theoretical carrying capacity in many arid, semi-arid and dry sub-humid areas, which has been the key factor in rangeland degradation.

▲ *Overcultivation*

Overcultivation is another important factor leading to desertification. Satellite imagery from remote sensing in 53 counties of Xinjiang, Gansu, Inner Mongolia and Heilongjiang, four provinces and autonomous regions conducted by the National Office of Agricultural Organization Plan, Ministry of Agriculture in 1997 showed that about half of the newly reclaimed cropland in the last ten years had been abandoned and desertified. According to the data, the annual loss of topsoil per hectare was around 15 tonnes resulting from cultivation on slopes of less than 5 degrees and 120–150 tonnes on slopes of less than 25 degrees. Under inappropriate policy guidance, large-scale reclamation of barren land was encouraged in the 1960s and early 1980s. But because forest protection and installation of irrigation facilities were ignored, most of the reclaimed lands were soon abandoned and became desertified.

▲ *Excessive collection of fuelwood and deforestation*

Excessive collection of non-wood forest products, including fuelwood, and deforestation are human activities that directly cause desertification. According to the latest national monitoring, 600 hectares of psammophytes vegetation was destroyed from 1994 to 1999, which caused an annual increase of desertified land of 120 hectares. In the last five years, the total area of destroyed natural vegetation amounted to 3 800 hectares, with annual destruction of 600 hectares of natural forest (*Populus euphratica* and *Tamarix*); 6 700 hectares of pasture in Gansu Province have been damaged by liquorice collection in the last five years.

▲ *Improper utilization of water resources*

One of the consequences of improper use of water resources is secondary soil salinization. More than half of the total cropland area has been affected by secondary salinization on the irrigated Yellow River bend plain because of faulty flood irrigation to the amount of 6.9–60.9 m^3 per hectare. Sixty-six percent of degraded cropland in dry sub-humid areas and semi-arid areas is affected by secondary salinization induced by faulty irrigation measures in Hebei Province. Moreover, large areas of rare natural vegetation are withering and dying from water shortages in the lower reaches of some rivers. For instance, huge quantities of water being pumped in the upper reaches of the Tarim River for agricultural development have caused a substantial decrease in water flow in the lower reaches, even to the extent that they have begun to dry up. Consequently many *Populus euphratica* woodlands in the lower reaches of the river have been impacted over the 100-kilometre stretch from Yingsu to Kurle. The situation in the middle reaches of the Heihe River in Hexi Corridor is similar. Floodwater flowing to the lower reaches has decreased from 1.2 billion m^3 in the 1960s to less than 500 million m^3 in the 1980s. *Populus euphratica* and *Tamarix* spp. woodlands have also diminished and even withered away due to overuse of water for farmland irrigation in the upper reaches. *Elaeagnum angustifolia* woodland is currently poorly conserved. The once flourishing Minqin Oasis is now suffering from water shortage in the low reach of Shiyang River and large areas of plantations are on the decline.

3. Land degradation monitoring and assessment methodology

To accurately understand the desertification process in China, the Chinese Government conducted the first round of national monitoring in 1994 and another two rounds of national desertification monitoring were conducted in 1999 and 2004. The revised Provisional National Desertification Operational Technical Regulation was adopted in 1998.

3.1 Methodology

Land degradation monitoring on a national scale integrated satellite image interpretation with ground sampling in 2004.

Field sampling was conducted in ten major provinces affected by desertification, with the sampling area accounting for 84 percent of the whole monitoring area. Satellite imagery covered 98 percent of the whole monitoring area. The field survey was assisted by GPS and GIS techniques were applied in data processing and mapping.

3.2 Desertification monitoring and assessment levels

According to the characteristics of desertification distribution, national desertification monitoring was conducted at three levels: macro-monitoring at the national level; periodic thematic monitoring and assessment in sensitive regions; and in-situ monitoring in commonplace regions.

Macro-monitoring was conducted every five years nationwide.

The main methodology of macro-monitoring is a ground survey combined with interpretation of remote sensing data, with the ground survey as the focus. The 3S (remote sensing, GIS, GPS) technology was adopted and a National Geographic Information Management System for Desertification was established, which provides significant support for policy decisions on combating desertification.

Thematic monitoring is conducted in areas combating aggravated, encroaching or active desertification and focuses on root-cause analysis and change dynamics.

The purpose of in-situ monitoring is to collect data relevant to indicators of desertification formation; development is monitored through long-term field observation stations that also serve as early warning systems. Twenty field stations are currently operational.

3.3 Monitoring and assessment indicators

The revised National Desertification Monitoring Operational Technical Regulation sets down indicators for field survey and satellite image investigation as shown in Table 1.

Key problems at the moment are: shortening of time-related assessment indicators, such as the Normalized Difference Vegetation Index (NDVI) coefficient of variation. Therefore, there is a need to use remote sensing images that are easy to use but have low accuracy, for example those generated by the Moderate Resolution Imaging Spectroradiometer (MODIS). The other is that socio-economic factors have not really been used as indicators for land degradation assessment though these indicators have been collected during investigation according to the operational technical regulation.

Table 1. Assessment methods and indicators for soil degradation types

Types	Indicators	Methods	
		Field	Remote sensing
Wind erosion	Vegetation coverage	✓	✓
	Soil texture or gravel content	✓	
	Sand cover layer	✓	
	Biomass or yield	✓	✓
	Surface morphology — sand dunes	✓	✓
Water erosion	Vegetation coverage	✓	✓
	Slope	✓	✓
	Percent of gully length or area	✓	✓
	Biomass or yield	✓	✓
Salinization	Salt content in soil	✓	
	Percent of salt path	✓	✓
	Proportion of halophytes	✓	
	Vegetation coverage	✓	✓
	Biomass or yield	✓	✓

3.4 Experiences in monitoring and assessment of desertification

After ten years of practice, China has a preliminary national desertification monitoring and assessment plan through integration of 3S technology with large-scale field surveys, verified by the three rounds of the national monitoring system. China's desertification monitoring system has taken shape, constituting macro-monitoring nationwide, thematic monitoring in sensitive regions and in-situ monitoring. Some scientific, technological and institutional aspects still need improvement.

Monitoring and assessment of desertification should be conducted at national, regional and community levels: Monitoring at the national level is mainly used to provide basic information to the macro decision-making of the government; therefore it should be macro-oriented in scope and could combine remote sensing with site surveys. The target group of community-level monitoring is farming communities; therefore it should be economically acceptable and practical. It should be conducted mainly by site inspection, the technology should not be too complex and the methods should be simple, inexpensive and practical.

Defining the methods and indicators of desertification monitoring and assessment: At present the desertification monitoring technology is not mature, and most of the monitoring remains at the scientific research stage. Therefore, the defining of indicators for desertification monitoring and assessment should be based on practical conditions. Some of the indicators are feasible in research, but might not be accepted by users, because they are not easy to master. Different indicators for monitoring and assessment should be defined for user and research purposes, taking into account the factors of low cost, ease of use and acceptability for users.

Establishing experimental areas for desertification assessment to explore technologies and methods for desertification assessment: In view of the remarkable differences in natural conditions, desertification causes and socio-economic conditions, it is recommended to establish experimental areas for desertification assessment in order to explore technologies and methods that are suitable and economically acceptable for desertification assessment in different areas.

Methods and indicators should be explored and tested, taking into account both the need for macro decision-making and the need for desertification control in farming communities.

4. China's Combating Desertification Programme and its progress

Within the framework of Chinese National Desertification Combating Planning, taking the "Three Norths" Shelterbelt Programme and the Sandification Control Programme for Areas in the Vicinity of Beijing as the principal components, China's Combating Desertification Programme also embraces a Land Conversion Programme, Natural Forest Protection Programme and the Key National Programme of Soil and Water Conservation.

4.1 Three Norths Shelterbelt Programme

China's Three Norths Shelterbelt Programme stretches over the 5 000 kilometre sand line in north, northwest and northeast China (the "Three Norths"), covering 551 counties (cities or districts) within 13 provinces (municipalities or autonomous regions), such as Xinjiang, Gansu, Qinghai, Ningxia, Shaanxi, Inner Mongolia, Shanxi, Hebei, Beijing, Tianjin, Liaoning, Jilin and Heilongjiang. With a total area of 406.9 million hectares, occupying 42.4 percent of China's total land area and with a population of 150 million, the programme area involves people of 22 nationalities including Han, Manchu, Mongolian, Tibetan, Hui and Uygur ethnic groups.

Through nearly 30 years (1978–2008) of construction within the first three phases, great achievements have been made in the Three Norths Shelterbelt Programme: an area of over 22 million hectares was afforested accumulatively, over 40 000 km^2 of desert was controlled, over 140 000 km^2 of soil and water eroded area was harnessed and some desertified land was effectively managed. The forest cover has increased from 5.05 to 6.06 percent. The accumulative afforested area is 5.9138 million hectares, which consists of afforestation of 3.528 million hectares, mountain closure of 1.9967 million hectares and aerial seeding afforestation of 0.389 million hectares. The real afforestation work has surpassed the original planning by 47.8 percent. A provincial shelterbelt framework has been basically established in Beijing, Tianjin, Liaoning, Jilin and Heilongjiang Provinces. During the implementation of the shelterbelt programme, a series of development models was set up, and some good demonstration sites were established in different areas. The basic layout of ecological forestry construction in the Three Norths area has been established and the environment of key controlled areas has been improved. Pronounced ecological, economic and social benefits have been achieved and the economic situation and people's living conditions have been elevated considerably. Thanks to the programme, many good examples of combating desertification of different types in different regions have emerged, the ecologies in some areas have distinctly improved, social economy has been harmoniously developed and people's living conditions greatly improved. The sub-humid arid model in Chifeng, Inner Mongolia, semi-arid model in Yulin, Shaanxi and dry model in Hetian, Xinjiang are good examples for China's future combating desertification thrust.

4.2 The Combating Desertification Programme in the Sand and Wind Source Areas Affecting Beijing and Tianjin

Due to the repeated severe sandstorms in northern China in the spring of 2000, the Chinese Government started to implement the 2001–2010 Plan of Combating Desertification Programme in the Sand and Wind Source Areas Affecting Beijing and Tianjin in 2001, which covers 75 counties (banners, districts or cities) in Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia with a total area of 458 000 km^2. The programme comprises four types: desertified grassland area, the sandy area in Hunshandake, desertified land interweaved by agricultural and grazing activities and the water source conservation area in the hilly and mountainous area of Yanshan Mountains. It is roughly calculated that about 57 703 million yuan[3] will be invested over ten years (including 30 104 million yuan for infrastructure investment and 27 599 million yuan invested by the central government), 2.02774 million hm^2 of farmland will be converted to forest or grassland, 4.94438 million hm^2 will be afforested, 10.62733 million hm^2 of grassland will be controlled with 5.68447 million hm^2 forbidden to grazing.[4] At the same time, 2.86 million m^2 of greenhouses will be established, 23 100 sets of fodder equipment purchased, 6 6059 water source programmes enabled, 47 830 water-saving irrigation units built,

[3] US$1.00 = 6.8 yuan (September 2009).

[4] hm = hectometre.

23 445 km^2 of comprehensive management for small basin areas completed and 180 000 people resettled for ecological reasons. Through measures such as protection of existing vegetation; forest and grass regeneration through desert closure; forest and grass establishment through afforestation and aerial seeding; conversion of farmland to forest and grassland; biological approaches, including grassland management and comprehensive harnessing of programmes for small basin areas, desertified land within the programme area will be basically brought under control. Ecological conditions will improve, windy and sandy climates and sandstorms will be greatly reduced, the expansion of desertification will be tempered and the ecological environment in the vicinity of Beijing will be enhanced considerably.

4.3 Cropland Conversion Programme

Conducting pilot work in 1999 and starting full-scale implementation in 2002, China's Conversion of Cropland to Forest and Grassland Programme carries great importance and is a core feature of the Programme for Developing China's West. The Cropland Conversion Programme is also effective in the permanent control of floods and droughts along the Yellow River. At the same time, the programme acts as a motivation for adjustments to the agricultural structure in western China, as a way to increase farmers' income and as an instrument to accelerate poverty alleviation.

The Cropland Conversion Programme encourages "conversion of farmland to forest, mountain closure and afforestation, food for work, and individual contracting". Those who conduct farmland conversion, afforestation and management benefit from the programme. The state provides farmers with grain and cash as a subsidy, which includes 100 kilograms of grain, 20 yuan and a lump-sum seedling cost of 50 yuan per year for each *mu*[5] of converted farmland in the Yellow River Basin and northern China. The term for subsidy is two years for conversion to grassland, five years for economic forest and eight years for ecological forest, tentatively. In addition, one *mu* of barren hill or land should be afforested when converting one *mu* of farmland, 50 yuan/*mu* will be given for buying seedlings by the government and the agricultural tax can be deducted and exempted. The duration for the contracting right for land conversion as well as afforested barren hills or land will be prolonged to 50 years. The contracting right can be legally inherited and transferred. When the contracting right expires, the contractor can renew the contract according to laws and regulations concerned. The Cropland Conversion Programme has spread to 25 provinces (municipalities or autonomous regions) nationwide and is going smoothly so far.

4.4 Natural Forest Protection Programme

Starting in 1998, covering such dry areas along the upper and middle reaches of the Yellow River as Qinghai, Ningxia, Inner Mongolia, Shaanxi, Xinjiang and Tibet, the Natural Forest Protection Programme aims at conservation of the rare water conservation forest (e.g. in Qilianshan Mountain and Tianshan Mountain) and desert vegetation (e.g. *Holoxylon ammodendron* and *Populus diversifolia*) in dry areas. Having improved the water conservation capacity along the upper reaches of continental rivers, the programme will make positive impacts on combating desertification.

4.5 Key National Programme of Soil and Water Conservation

Projects concerning dry areas within the Key National Programme of Soil and Water Conservation are: the Soil and Water Conservation Project along the Yellow River, Soil and Water Conservation Project along the Songhuajiang River, Liaohe River and rivers in northeast China and the Soil and Water Conservation Project along continental rivers. Taking comprehensive harnessing of a small basin area as its main target, the Soil and Water Conservation Project along the Yellow River consists of construction of basic farmland, development of water-saving irrigation through rain collection, integration of arbors, shrubs and grass with emphasis on shrubs, conversion of cropland to forest and grass, rehabilitation of vegetation, construction of key projects for gully and silt arrester management and control of gully erosion. With emphasis on control,

[5] 1 *mu* = 0.0667 hectare.

priority projects will be deployed to areas with abundant and thick sand, exposed arsenic rock, interweaved agricultural and grazing activities and grassland hit by degradation, desertification and salinization. The Soil and Water Conservation Project along Songhuajiang River, Liaohe River and rivers in northeast China embraces integration of technical measures with soil and water conservation measures, reconstruction of sloping cropland, protection of black soil, plantation of shelterbelt forest, control of wind erosion, optimization of grassland, prevention of desertification and degradation. The Soil and Water Conservation Project along continental river drainage includes continental rivers in Inner Mongolia, Hexi area, Zhunge'er, central and western Asia, Talimu River, Qinghai Province, Qiangtang area and Erqisiwai River, which are within the scope of Xinjiang, Tibet, Inner Mongolia, Gansu, Qinghai and Hebei. Taking protection of ecological oases as its priority, with emphasis on oasis agricultural zones, the project mainly embraces soil and water conservation, water-saving irrigation and plantation of protection forest.

5. The principal measures and experiences in China's combating of desertification

China's combating of desertification has made significant achievements. Holding the belief of "humans first", we have always adhered to the law of nature, the rule of economic development as well as the principle of "prevention in the first place, with scientific management and reasonable utilization". We have also taken measures to mobilize participation of the whole society to build up an ecosecurity system, with forest and grass being principal components, aiming to increase farmers' and herdsmen's income, as well as coordinated development of the economy and society. The main measures are:

Combating actions are in accordance with related laws and regulations: We have implemented a series of laws that constitute a comprehensive legal system, of which the main body is the Law on Combating Desertification, along with the Forest Law, Grassland Law, Environment Law, Law on Meteorological Services, Law on Water and Soil Conservation, Law on Soil Management, etc. We have established a responsibility mechanism for combating desertification and vegetation protection; implemented a restriction system on overcutting, overgrazing and overcultivation; a system of grassland ecological protection and construction; a water utilization system as well as an environmental impact evaluation system for exploitation and construction projects in sandy land areas. All these measures have provided guarantees for standardizing natural resource protection and soil utilization and also for preventing human-induced damage.

Implementation of projects: Farmland protection and forest expansion have been initiated; since the 1980s, the Three Norths protection forest system has been under construction; in the 1990s, a national project for preventing and combating desertification and sandification was launched. At the beginning of this century, a series of major ecological enhancement projects was initiated, such as the Grain for Green Project, natural forest protection, Beijing–Tianjin wind and sand source control, small watershed management, etc. Combating desertification has made great progress and effectively boosted socio-economic development.

Scientific means: We have set up an expert consulting institute for scientific decision-making and formed a comprehensive monitoring and evaluating system to manage the occurrence and development of desertification. We scientifically evaluate the achievements and improve the level of scientific decision-making simultaneously. We have enhanced basic scientific and applicable research to solve key technological problems, and by continuous summarizing and fine-tuning, we have created over 100 sets of technological paradigms such as the "Five-in-One" railway protection forest construction pattern, the Sand-prevention Engineering System for Highways in Desert Regions and the sparse and narrow forest belt with small network protection pattern. Moreover, we have established a sound technique-promoting and service-providing system, strengthened the application of advanced techniques and scientific achievements, formulated synchronized implementation of key construction projects and science/technology support projects (distributing 3 percent of ecoproject investment into science and technology support), thereby improving the quality and efficiency of combating desertification through scientific means.

Comprehensive measures: We have formed a coordinating group consisting of 18 departments, with the Head of the State Forestry Administration as the group leader to execute macro-management and form a mechanism in which the Forest Department is responsible for organizing, coordinating and supervising activities, assisted by departments such as agriculture, irrigation, soil, climate and environmental protection. All sides are organically combined to work together specifically.

Policy guidance: The State Council issued "the opinions on several measures to combat desertification" followed by "decision on further strengthening the work of desertification combat" in 2005. The government has provided support in the form of financial input, credit, tax and fee holidays, rights' and interests' protection and ecological enhancement compensation and has practised the policy of "who combats, will manage and benefit", which to a large degree stimulates positive attitudes, initiative and creativity; now combating desertification has taken on a new look — the joint participation of the nation, society and individuals.

6. Conclusion

- Before the 1990s, China's desertification assessment in dry areas remained at the research level instead of a productive level for national decision-making or guidance. Since 1994, China has conducted national desertification monitoring twice. The escalation of China's desertification monitoring from the research level to the productive level was motivated by urgent demands by China's national combating desertification drive. In order to keep desertification within limits and to combat desertification through large-scale projects, China must comprehensively master and know general desertification conditions and conduct monitoring and assessment of desertification of different types in different regions. Therefore, attention should not be paid to monitoring work without demand for production.
- As the basis for monitoring and assessment, scientific research is essential. However, assessment work should be accelerated and meet the needs of production instead of remaining at the research level over a long time. The existing research results should be practised, tested and improved through actual monitoring and assessment at the productive level. Only after integration with production, can the research results be proved feasible or otherwise, and some adjustments and improvement can be made accordingly. If research sticks to its original level, its quality will not be increased. China has made efforts to increase its desertification monitoring and assessment level.
- Caution must be attached to the acceleration of desertification monitoring and assessment from the research level to the productive level, especially to the larger-scale regional or national levels. When different opinions from several specialists occur, this calls for even more caution to avoid serious economic losses. Based on the adoption of various research results, China's National Action Plan on Desertification Monitoring and Assessment has been developed and tested after adoption of specialists' suggestions and review of a specialist committee consisting of experts from different fields. In other words, during the process of implementation, problems will be found and fed back to the government, which will organize specialists to make relative adjustments according to the feedback for continuous improvements in the plan.

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Land degradation assessment in drylands in Indonesia

Abstract

Rising population and rapid demand for land for settlement in Indonesia have resulted in the shifting of agricultural land use to non-agricultural purposes, which gradually causes a decline in potential agricultural land annually. As a result, agricultural development increasingly progresses towards steep and sloping land and stony upland areas and destroys protected forest, which in turn causes water resource degradation. Furthermore, the increasing water shortage forces the farmers to shorten the traditional fallow periods. These factors cause declining productivity and increasing food deficits for the smallholder population. Considering the situation, land degradation assessment needs to be carried out at national, subnational and local levels to recognize the strategic and real problem on the ground. In order to meet the sustainability of land resources and to guarantee optimal and stable crop yields in temporary or permanent parcels of agricultural land, land degradation should be monitored and early symptoms used as an early warning tool. However, Indonesia needs cost-effective methods for land degradation assessment and monitoring due to the vast area of the country.

Introduction

Signs of land degradation include accelerated soil erosion, increasing salinization of soils, near surface groundwater supplies and reduction in the productivity of dryland ecosystems, with attendant impoverishment of the human communities dependent on them. A combination of climatic stress and land degradation may lead in turn to extreme social disruption, poverty, migration and famine. These conditions have started in several regions of Indonesia, especially in the central and eastern parts.

Indonesia attaches great importance to the physical problems generated by land degradation and their effects on local communities. The most obvious impact is low agricultural productivity that can lead to widespread poverty. In Indonesia, a country with 17 508 islands, high population growth rate and uneven population distribution have created severe pressure on land resources. The population has risen from 120 million in 1971 to 250 million in 2008 (Figure 1), with an annual growth rate of 2.7 percent. Without any positive intervention through appropriate environmental management programmes, this trend may lead to increased land degradation and in turn desertification.

Population pressures on the land are mostly felt in the densely populated areas of Java, which is inhabited by 950 people/km^2. To meet population demands, more forests have been converted to agricultural lands while agricultural lands are converted without any control for urban and industrial uses.

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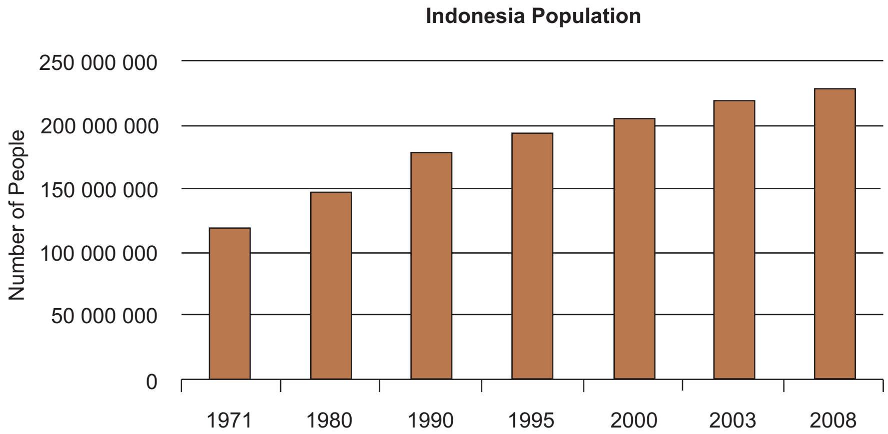


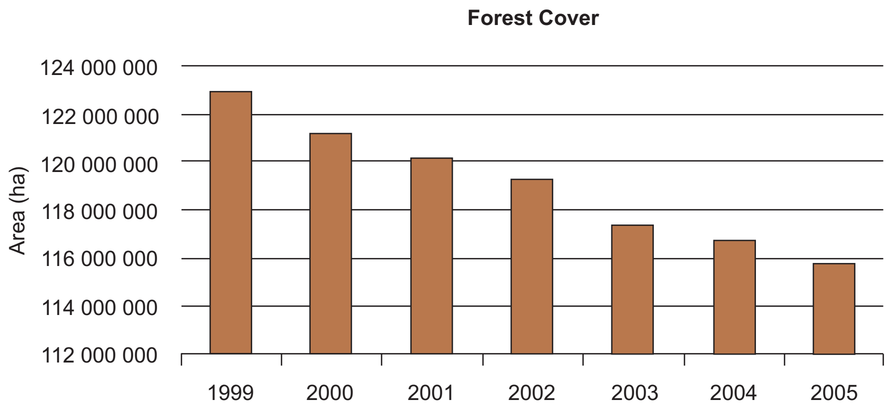


Figure 1. Population growth (1971–2008) and forest cover loss (1999–2005)

Land degradation assessment in drylands

The extent of degraded land in Indonesia is increasing rapidly especially in the dry areas due to shifting cultivation, misuse of land resources and overgrazing. These practices result in shrubland, wasteland and unproductive land, and in turn increased poverty. Recent data on deforestation in Indonesia showed a rate of 1.08 million hectares per year until 2008. The latest data (2007) showed that degraded land had reached 77.8 million hectares (including the slightly degraded class), which is more than double the figure of 34.8 million in 2001 (Table 1). The distribution and details of degraded land in 2007 are shown in Figure 2.

The method and process of land degradation classification is shown in Figure 3 in which a scoring system was applied. Basically, the first step is mapping land units, which are created from information/maps on slopes, erosion, land management and productivity and outcrops. The score is ranked from 1 to 5 but the total score

Table 1. Increasing degraded land area in forest and non-forest areas of Indonesia from 2001 to 2007 (million hectares)

Area	2001	2007
Protection forest	4.0	9.3
Conservation forest	1.9	4.4
Production forest	13.8	25.8
Non-forest lands	15.1	26.8
Total	34.8	77.8

Figure 2. Distribution of degraded lands in Indonesia

will depend on the weight of each parameter; for example the weight for the slope map is 20 percent while that for outcrops is only 5 percent. The score will be counted by multiplying individual scores for each information bracket with its weight. A land unit with a total score of less than 150 will be classified as 'very degraded' and one exceeding 450 will be classified as 'not degraded'.

In the eastern parts of Indonesia, which are considerably drier, climatic factors contribute to the dryness and arid conditions in various parts of the islands. Some areas have recurrent dry conditions, for instance the islands of Lombok, Sumbawa, Sumba and West Timor. Some areas even bear desert characteristics, as can be seen in some parts of Lombok, Sumbawa and Central Sulawesi.

In West Nusa Tenggara (NTB) Province the total degraded land area has reached 360 675 hectares, comprising 98 210 hectares in forest land and 262 465 hectares in non-forest land. While in East Nusa Tenggara (NTT) Province, it has reached 1 356 757 hectares, comprising 299 291 hectares in forest land and 1 057 466 hectares in non-forest land.

Land degradation in NTT and NTB is mainly characterized by:

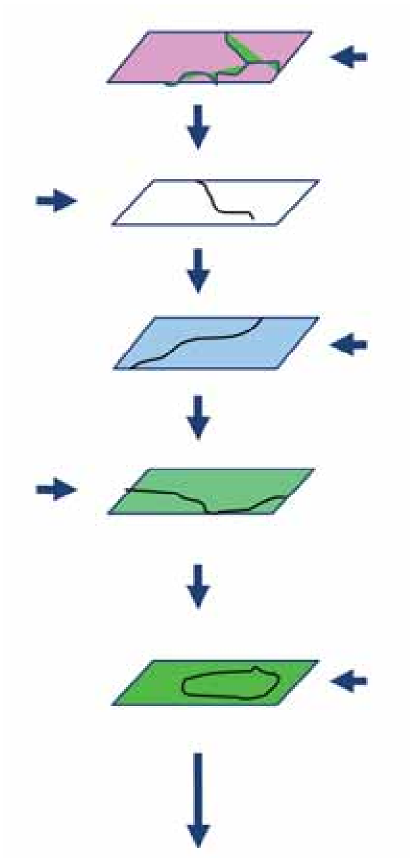
- The impacts of overgrazing and bush fires;
- Low rates of topsoil development due to fire hazards;
- Thin layers of topsoil and rocky soil created naturally by soil age, landslides and rill/interrill erosion;
- High sedimentation rates downstream owing to severe erosion and floods.

The biophysical conditions of NTT and NTB Provinces, which are closely related to land degradation problems, are characterized hereunder:

- NTT and NTB Provinces are islands dominated by hilly topography, 26–46 percent slope, with young sedimentary rocks and volcanic parent materials and high erosion sensitivity;
- Low vegetative cover, low infiltration rate, high runoff and risk of floods;
- A dry season of nine months and a rainy season of three months with high erosivity via rainfall;
- Land productivity is very low, thus requiring many inputs from farmers to maintain production;
- High sediment load during floods; this has led to mangrove forest degradation, downstream pollution and other negative environmental impacts.

Slope steepness map (%) (weight: 20%)	
Class	**Score**
0–8	5
8–15	4
15–25	3
25–40	2
> 40	1

Productivity map (weight 30%)		
Class	**(%)**	**Score**
Very high	> 80	5
High	61–80	4
Medium	41–60	3
Low	21–40	2
Very low	< 20	1



Erosion map (weight: 15%)	
Class	**Score**
Slight	5
Moderate	4
Severe	3
Extreme	2

Management map (weight: 30%)	
Class	**Score**
Good	5
Medium	3
Bad	1

Outcrop map (weight: 5%)	
Class	**Score**
Low	5
Medium	3
High	1

Intersect/overlay

Land degradation map

Land degradation level	
Level of degradation	**Total score**
Very degraded	120–180
Degraded	181–270
Slightly degraded	271–360
Potentially degraded	361–450
Not degraded	451–500

Figure 3. Degraded land classification in Indonesia

Another relevant area of dryland degradation is Central Sulawesi Province, which has degraded land of 518 262 hectares, consisting of 231 360 hectares in forest land and 286 902 hectares in non-forest land.

The topography of Palu Valley is characterized by sloping land with one-third of the area having slopes exceeding 40 percent, distributed among alluvial and fan deposits. This valley has the lowest level of rainfall in Indonesia (519.6 mm/year) with average temperatures ranging between 23 to 33ºC. Thus many parts of Palu Valley are categorized as degraded land. Currently, about 13 000 hectares out of the 60 000 hectare area of Palu Valley are described as critical/bare land.

Most of the Palu Valley's inhabitants (400 000) live in these degraded lands on which they depend for subsistence. In the past, many local community-learning models were used to manage these marginal areas.

Unfortunately this indigenous learning has been undermined by new systems and methods that are not so environmentally friendly. This has generated rapid degradation in many areas of Palu Valley. It is not surprising that up to now more than 50 percent of Palu Valley has become unproductive.

To arrest the deteriorating condition of the land, efforts have been made to improve the land condition, such as reforestation and the regreening programme in the 1980s. However, this programme was unsuccessful because of the wrong approach and lack of community support. Therefore, to suppress the land degradation process, a community model approach needs to be developed. One of the prerequisites is involving many stakeholders (communities, the government, academics, NGOs, non-profit-making organizations, youth groups, religious groups etc.) in the planning, implementation, evaluation and monitoring of the model.

Besides the need to strengthen its capacity to control forest and bush fire, Indonesia is expected to explore effective ways to mitigate the impact of drought, and to promote water management strategies aided by seasonal forecasting methods and other associated measures for land degradation amelioration.

Socio-economic and cultural settings

In the dry areas of NTT, NTB, Central Sulawesi and the Eastern Part of Indonesia, typical socio-economic and cultural factors affecting land degradation and deforestation are:

- Limited available knowledge and low innovative ability;
- Low participation of local communities;
- Low income and capital;
- Food shortage due to water shortage, poor soil fertility management and insect attacks;
- Inadequate local community empowerment; and
- Lack of conservation practices.

These biophysical, socio-economic and cultural constraints have affected the implementation of land rehabilitation, particularly in dry areas.

Action for rehabilitation of degraded land

The land area of Indonesia encompasses 189.15 million hectares. Forest occupies 120.35 million hectares or 63.44 percent of the total land area. A major portion of the Indonesian forest serves as the world’s ‘lung’; it can absorb greenhouse gas emissions and thus help to balance the world’s ecosystems. From the domestic standpoint the tropical rain forest of Indonesia is constantly maintaining its economic, social and environmental roles for communities within and outside the forest areas. Consequently, the government is addressing forest management to consolidate continuous benefits for present and future generations.

As mentioned earlier, forest utilization and industrialization have resulted in degraded forest land areas comprising 77.8 million hectares (Table 2), in which approximately 47.6 million hectares are ‘slightly degraded’, about 23.3 million hectares are regarded as ‘degraded’ and the remaining 6.8 million hectares are ‘highly degraded’.

The National Movement on Forest and Land Rehabilitation (GERHAN)

Whether slightly or highly degraded, such land cannot bear its economic and environmental functions, including its ability to absorb greenhouse gases, particularly carbon dioxide. An adverse impact of the reduced capacity of tropical forests is disturbed ecological balance. In tandem, unabsorbed carbon dioxide is released into the atmosphere generating global warming and eventually climate change.

This chain reaction indicates that tropical forests should be returned to their original condition. In this context, efforts should include the conservation and maintenance of the remaining tropical forests and rehabilitating degraded forests and land. As a developing country, Indonesia cannot do this alone. Some of the funds,

Table 2. Classification of degraded lands in forest and non-forest areas (hectares)

FUNGSI KAWASAN	DEGRADED LAND CLASSIFICATION			TOTAL
	Slightly degraded	Degraded	Highly degraded	
Non-forest land	**16 082 933**	**8 587 558**	**2 102 753**	**26 773 245**
Forest lands	**31 527 148**	**14 718 675**	**4 787 813**	**51 033 636**
Conservation forest	3 002 261	1 021 015	332 077	4 355 352
Protected forest	6 051 764	2 527 270	724 664	9 303 699
Production forest	8 919 109	4 284 581	2 052 204	15 255 895
Conversion forest	5 367 368	4 212 741	969 213	10 549 323
limited production forest	8 186 644	2 673 067	709 655	11 569 367
JUMLAH	**47 610 081**	**23 306 233**	**6 890 567**	**77 806 881**

technology, information and management skills should be outsourced from developed countries to achieve rehabilitation goals because their success will benefit the whole world.

At present the Government of Indonesia is carrying out the National Movement to Rehabilitate Degraded Forest and Lands, the so-called GERHAN programme. This movement invites donors and other participants because the thrust is not solely to rehabilitate degraded lands. The outcome will eventually rehabilitate the environment for protected, threatened and endangered flora and fauna.

GERHAN is mandated by the Forestry Law of 1999. The law states that the forest area should encompass a minimum of 30 percent of the watershed or island. In particular the forest should protect the watershed areas because they are important for agriculture and provision of potable water for communities. The rest of the forest within an island should function well to develop economic, social and environmental benefits. In fact, the total forest area of Indonesia is about 64 percent of the total land area. However, as earlier stated, the presence of degraded land areas greatly reduces this figure and it is further reduced when one goes from one island to another. In fact, field observations have indicated that what is formally called forest is barren, savannah-type land where unproductive forest grows sparsely or is invaded by *Imperata cylindrica* grass. GERHAN was created for this reason.

GERHAN became operational under the Joint Decree of three Coordinating Ministers — of Community Prosperity, of Economics and of Politics and Security. The Joint Decree was promulgated in 2003. Formally the decree addressed the Formation of the Coordinating Team to Improve the Quality of Environment by National Forest Rehabilitation and Reforestation.

Since then activities have focused on forest rehabilitation and reforestation during which continuous evaluation of the programme and achievements as well as impact assessment have been carried out. Evaluation covers the mechanism (management, administration, reporting systems), organization as well as technical, economic and social benefits. It has indicated that there is room for improvement. To enhance its organizational effectiveness and to achieve optimal results for forest rehabilitation and reforestation, the Joint Decree was elevated to a Presidential Regulation in 2007. The elevated status of the programme showed the commitment of the president to address forest rehabilitation and reforestation as the only ways to decelerate forest degradation and deforestation. The forestry sector has a leading role.

The programme specifies that forest benefits should be distributed to other economic sectors. The multidimensional benefits of the forest rehabilitation and reforestation programmes are the purview of the parties that enjoy them. Thus, the programmes are executed through close government cooperation (central, provincial and district levels) and community participation.

There are three models for forest and land rehabilitation. The first model is provision of incentives; the second model is full government investment and the third model is government-funded local development. In model 1, incentives are provided to communities outside the forest areas who are willing to participate outside the programme. The government provides high quality seeds and funds to build facilities. The main attribute of model 1 is participation, provision of adequate numbers of high quality seeds and an established organization that is independent of the programme. The model is applied to the rehabilitation of community forests, the rehabilitation of the environment such as urban forests, trees along highways, soil conservation plants, rehabilitation of mangrove forests and other forest rehabilitation.

The second model is applied to forest under the management of the Department of Forestry — conservation, protection and production forest areas. The activities are fully funded by the government including the provision of seeds and seedlings, planting materials, maintenance of juvenile plants and construction of conservation structures that involve the community within and adjacent to the forest areas. The activity also covers forest rehabilitation in production, conservation and protection forests. The activities may be executed by state-owned companies in the forestry sector, including the development of Muna teak, protection of catchment areas for natural and artificial dams and lakes as well as mangrove forests.

The third model is an effort to increase forest productivity and community participation. It is basically an endeavour to develop land and forest management techniques and to encourage community participation. It is fully funded by the government. The funds are channelled to the participants through block grants to farmers' groups for the conservation of rare species and the application of intensive silviculture; rehabilitation of degraded lands via plotting systems; the development of seed production areas; social forestry and community–business partnerships.

The government's commitment is increasing economic growth, resisting negative dynamics and is evenly distributed. As such, investments are rising, job opportunities are being created and poverty is being reduced, commonly conceptualized as Pro Poor, Pro Job and Pro Growth (the 3Ps). Given current problems, future forestry programmes need to effect the three concepts to maintain a healthy status quo. Forestry development needs to create a favourable investment climate enabling the business sector to stimulate economic growth (Pro Growth). Eventually, sustainable forest management should be achieved on a constant basis.

Directly or otherwise, high economic growth created by GERHAN reduces pressure created by high Indonesian unemployment. GERHAN as a forestry programme is not only capital intensive but also very suitable to Indonesian demographics providing worker-intensive job opportunities. GERHAN is an economic buffer in the Indonesian economic spectrum (Pro Job).

Furthermore, GERHAN needs to improve peoples' prosperity. The lesson from the era of the New Order (1965–1997) was that economic growth and job creation failed to improve peoples' prosperity as there were no distribution effects. Trickle-down effects created prosperity for only a limited number of people. GERHAN needs to secure evenly-distributed prosperity, especially for the poor (Pro Poor).

To probe how effective GERHAN has been in attaining the 3Ps, a review was conducted at 31 Watershed Management Centres (WMCs) throughout Indonesia. Deeper review was conducted at seven WMCs, i.e. Cimanuk Citanduy WMC (West Jawa–Central Jawa), Way Seputih Way Sekampung WMC (Lampung), Asahan Barumun WMC (North Sumatera), Kahayan WMC (Central Kalimantan), Kapuas WMC (West Kalimantan), Benain Noelmina WMC (Nusa Tenggara Timur) and Dodokan Moyosari WMC (Nusa Tenggara Barat). Further review was also conducted to understand how far GERHAN could further improve environmental quality and shifting attitudes and societal perspectives after implementation. Based on 2003–2005 data, the review indicated:

- Programme implementation (until 2007): 69.24 percent or 2 461 761 hectares out of a total target of 3 000 000 hectares. Incurred expenses were IDR8.62 trillion (US$1.00 = IDR9 693, September 2009);

- Pro Poor: GERHAN improved societal income at an average of 16.91 percent, (from IDR4.32 million/family/year to IDR5.09 million/family/year). The highest income improvement attained at Way Sekampung Seputih WMC (Lampung) was 42.31 percent and the lowest at Kahayan WMC (Central Kalimantan), 3.83 percent;
- Pro Job: on average, GERHAN absorbed 35 785 persons/year at every WMC (Indonesian overall absorption is 1 109 335 persons/year). The highest job absorption was at Benain Noelmina WMC (Nusa Tenggara Timur) totalling 66 296 persons/year and the lowest at Kahayan WMC (Central Kalimantan) totalling 15 420 persons/year;
- Pro Growth: GERHAN is estimated to have produced 82.6 million m^3 or on average 27.51 million m^3 of timber annually (worth IDR62.42 trillion or on average IDR22.08 trillion/year). Regarding non-timber products, every WMC delivers on average 1.28 million tonnes/year worth a total of IDR11.65 trillion or on average IDR3.88 trillion/year. Therefore the government has recouped a considerable portion of the expenses incurred between 2003 and 2005;
- GERHAN also successfully promoted forest farmer group participation at 30 721 groups (1.54 million families). At an average of four persons/family, GERHAN recruited 6.1 million persons.

Agrosylvipasture and *embung* development

Most of the topography in Nusa Tenggara islands is dominated by hilly areas covered by savannah grass. Annual rainfall is less then 1 000 mm with 100 days of rainfall. Temperature and humidity range from 20–33.8ºC and 27.3–50 percent, respectively. The main soils are Entisols, Alfisols and Ultisols (USDA *Soil taxonomy*). Family income depends strongly on food crops such as paddy rice, maize, cassava and legumes and annual crops such as cashew, coffee, betelvine and areca nut. Most farming practices employ mixed cropping, alley cropping, strip intercropping and mixed intercropping systems.

A study of natural resources and environmental management in several villages in the subdistrict of Karera District of East Sumba showed that the environment has degraded gradually. These conditions significantly affect agricultural production and family income. The main cause of environmental degradation is improper natural resource management such as inappropriate soil conservation practices, slash-and-burn shifting cultivation and overgrazing as well as increasing population. Some attempts have been made to mitigate these problems but they have not addressed people’s involvement in identifying environmental issues that affect their farming practices and how to overcome them through local knowledge. Hence, the participative-plus approach is a promising way to improve degraded environments and significantly improve agricultural practices. The participative-plus concept focuses on interaction between farmers and scientists (students and lecturers) to identify the main natural resources and environmental problems, to determine improvement measures and to make them practical based on their knowledge. Eventually, degraded natural resources and environments can be improved thus enhancing food security and family income.

Some soil conservation systems have been practised by farmers such as growing legume trees that function as a source of organic matter and runoff barriers; growing grass as a source of livestock food and to improve soil physical properties and soil nutrients; applying liquid organic fertilizer to improve soil nutrients and food crop yields; and diversifying agricultural practices such as combining root crops and food crops in different cropping systems etc. A number of studies have shown that improving agricultural practices has resulted in better crop yields, better soil nutrient status, decreased runoff and lower food deficits during the dry season. However, these studies require replication in different environmental conditions, at different times and under different socio-economic conditions and cultures. An example is Karera District of East Sumba, which is vulnerable to extreme change in the dryland environment. Therefore, soil and plant management is characterized by natural and human components that affect food security and family income.

Famine is mainly caused by crop failure due to erratic rainfall and the short farming season. This area receives about 850 mm of rainfall annually, most of which falls in a two-to-three month period that is followed by a long dry season. During this period, there is commonly no rainfall for six to eight months. As a result, the only harvests of the year are often disastrous.

The nature of the soil (with limestone as parent material, mostly Alfisols) should allow the storage of water from the rainy seasons in holes dug in the soil surface for irrigation and other purposes during dry spells. Integrating the staple crops with legume fodder and small cattle, fruit trees, and wood trees in farms would improve soil and water conservation in the area as well as farmers' economy. The establishment of multipurpose trees and wood trees together with undercanopy crops and legume tree fodder in the forest areas would improve environmental and living qualities as well as the economy in the region.

To stimulate social development in Nusa Tenggara to combat land degradation and strengthen agricultural activities, four agricultural development strategies are deployed by farmers:

(1) Staple crop production diversification in the farm with fruit trees, industrial trees, and wood trees, to improve farmers' income.

(2) Legume tree fodder and grass production for small cattle through the implementation of an agrosylvipastoral system for economic and conservation purposes.

(3) Rehabilitation and creation of *embung* (traditional water ponds) and other rainwater harvesting techniques to improve rainwater-use efficiency.

(4) Establishment of multipurpose trees and wood trees together with undercanopy crops and legume trees for fodder in the forested land.

With the implementation of these strategies, stronger and more diversified crop and cattle production in the dry area of Nusa Tenggara would ensure that food supply to the local population is sufficient and of good nutritive value. Important additional income for farmers could also be provided through the sale of cattle and fruits, which are high value commodities. Establishing fruit and wood trees both in farms and forested areas will ensure improved soil and water quality as well as environmental health.

Activities in West Nusa Tenggara (NTB)

Rainfall occurs over 1.5 to three months per year with less then 1 000 mm/year. The dry season lasts for six to eight months. The landscape is hilly with Alfisols and limestone as the parent material; slope steepness exceeds 25 percent. Land cover was 100 percent forest (various local wood trees) before 1977; however, within the period 1977–2003 the land was used for subsistence agriculture and it is now bare; very few trees can be seen.

At present, agricultural activities are carried out by planting staple crops such as upland rice, maize, soybean, groundnuts and beans. Livestock include goats, cows and buffalo (in reasonable numbers). Tree cover consists of sesbania, cashew and coconut (in very limited numbers). Farms use rainfed irrigation plus *embung*. Agriculture is the dominant activity but is managed poorly and conducted via unsustainable farming practices.

The main constraint is the harsh climate, short rainy season with erratic rainfall and long dry season. The fertility of the soil is poor and most farmers are labourers and smallholder farmers. Producing staple food crops is still the main goal for most farmers. Animal husbandry is viewed as a supplementary activity to farming and not as a potential main source of income. Poverty and unemployment are widespread and population growth is high.

Activities recommended to improve farmers' livelihoods are:

1. Strengthening and empowering community participation.
2. Strengthening community development and local initiatives (*awiq-awiq*/local regulations).
3. Strengthening coordination and collaboration among stakeholders.

4. Rehabilitation and construction of *embung*.
5. Diversification of crops with the inclusion of fruit trees (mango, jackfruit, sawo, sirsak, jambu batu, etc.), industrial trees (cashew, asam), legume fodder (sesbania, leucaena, gliricidia, cotton tree), grasses (elephant grass) and wood trees (mahogany, sengon, teak, etc.).
6. The establishment of agroforestry in forest areas with the inclusion of multipurpose trees (jackfruit, cashew, kemiri), wood trees (mahogany, ampuphu, neem, sengon, teak, etc.) and fodder trees (sesbania, leucaena, gliricidia, cotton) and undercanopy grass and medicinal plants (elephant grass, ginger and other medicinal plants).
7. Establishment of the agrosylvipastoral system of 'layered living fences' (*Pagar Hidup Berlapis*). Five to ten trees are grown on one hectare of land for small livestock (goat, sheep and deer). The system is meant to eradicate poverty in dryland areas through improved farmers' income from selling livestock fed with tree fodder. The system is also intended as a starting point to trigger the establishment of more integrated and comprehensive agroforestry in dryland and other land types. Poverty eradication is expected to be completed in a relatively short time, six to 12 months.
8. Small livestock (goat, sheep and deer) production.

Results anticipated from implementation of the recommendations are:

1. Increased local people's participation in development through participatory activities.
2. Empowered women will improve gender equity, which usually leads to improved women's health with ripple effects for families and communities.
3. Improved capacity of key institutions in the community to guide economic policy and private sector development.
4. Improved development and application of policies for environmentally sustainable development.
5. Field experiment demonstration would provide visual evidence for the communities and a site for the local population to learn by doing and finally adopt the method into their practices.
6. Creation of efficient rainwater storage ponds would increase water availability and soil conservation in the surrounding areas. This activity would also improve farm productivity and provide food security to farm owners and other households in the villages as crops and young trees could then be irrigated during the dry season. Well-nourished people are the basis of prosperous economies.
7. Cattle and fruit production will significantly improve farmers' income and create employment in the region.
8. Alleviation of poverty will allow farmers to organize their social development. Families will be able to send their children to school.
9. Activities conducted are expected to reinvent local technology and sociological approaches and strategies to combat land degradation, and may be potentially adopted for use in other regions.
10. Activities conducted are expected to reduce land degradation challenges in the region.

There are a number of bonuses in NTB: Roads are perfect and distances are relatively short. The infrastructure is adequate and the political situation is quite stable. The major challenge is timing for crop and tree planting because the rainy season is short. The availability of water is also crucial for the successful livestock production programme.

Rainwater storage ponds will be designed to improve farm productivity. This initiative is in perfect agreement with the will of the UNCCD which places emphasis on poorer groups and on capacity building in combating desertification. The capacity of agricultural production will be increased, but more importantly, the ability of local people to take charge of their development will be improved.

The diversification of crops with fruit trees will contribute to the development of an agricultural economy in NTB where subsistence agriculture has traditionally prevailed. The development of an agricultural economy in NTB will certainly be an important step toward equitable economic growth in Indonesia.

For development to be sustainable, it must respect the environment. This is especially true in the case of agricultural development because agriculture is the largest interface between human beings and their environment. This is why the potential environmental impacts of the implementation of rainwater storage ponds and diversification of cropping systems with fruit trees, fodder and tended livestock in the farm and forest area management with the inclusion of multipurpose trees and fodder production will be considered first.

National strategy to combat land degradation

Learning from the local success of the agrosilvipastoral practice described earlier therefore creates the need to develop input for national strategy formulation to combat land degradation. The national strategies that have been included in the National Action Programme to Combat Land Degradation are:

1. Public support and participation are critical for applying and implementing methods for degradation prevention and rehabilitation control.
2. Developing a partnership with local institutions and community and non-government organizations for effective implementation of land degradation control.
3. Coordination with implementation of the UNCCD and CBD for provision of support and resources.
4. Strengthen cooperation with related regional institutions, regional UNCCD Thematic Programme Networks and international organizations.
5. Develop the capacity to be more consolidated; manage and deploy existing financial resources and strengthen the capacity to negotiate with international and national agencies for increased financial support.
6. Establishing priorities and development of action plans through active involvement in decision-making by local communities in implementation, monitoring and evaluation.
7. Representative communities should be fully engaged in all activities at all levels (planning, implementation, monitoring and evaluation).
8. Use best practice knowledge and robust technologies including traditional knowledge and wisdom.
9. Awareness raising about good environmental quality and sustainable agricultural development.
10. Projects should be holistically concerned about the unique characteristic of the community in the respective degraded land (integrated and special projects).
11. Projects should be concerned with long-term security investment through a good and attractive land tenure system.

A thematic programme launched to combat land degradation has been included in the National Action Programme to Combat Land Degradation, elements include:

A. *Providing enabling conditions*

a. Strengthening existing legislation to support the programmes.
b. Enacting new laws (if necessary) is needed where the existing legislation is insufficient to accommodate and support the implementation of the programmes.
c. Developing human resources to enhance local people’s knowledge and benefit from the implementation of the programmes.
d. Enhancing effective institutions to effectively execute the programmes.

e. Promoting public awareness so all related stakeholders will be aware of the importance of the programmes and can contribute and be involved.
f. Developing a land titling programme to ensure the security of the land where the programmes are being implemented.
g. Streamlining development programmes through training, field schools and extension.

B. *Land degradation inventory and monitoring*

a. Monitoring of soil erosion and sedimentation.
b. Inventory and mapping of degraded land using appropriate technology including remote sensing techniques.
c. Identification and classification of degraded land.
d. Management of land degradation data and a related information system.
e. Identification of the root causes and impact of land degradation on socio-economic and socio-cultural aspects.

C. *Promoting agroforestry*

a. Developing agroforestry demonstration areas for different soil fertility and land conservation techniques.
b. Promoting local knowledge and technology in agroforestry practices.
c. Providing high quality seed/planting material and dryland farming inputs.
d. Promoting indigenous species for multipurpose plantations in drylands.

D. *Monitoring and mitigating the impact of drought*

a. Strengthening research activities for drought-resistant crops.
b. Development of sustainable dryland farming systems.
c. Improvement of early warning systems.
d. Formulation of drought contingency plans.
e. Monitoring of water availability.
f. Monitoring of climate change impacts.

E. *Prevention of land degradation*

a. Extension and strengthening of local people's participation.
b. Promoting soil conservation technology options.
c. Campaigning on the danger of land degradation and the benefits of soil conservation.
d. Providing credit schemes for conservation farming systems.
e. Providing guidelines and standards for soil conservation techniques.

F. *Rehabilitation of degraded lands*

a. Review of completed and ongoing land rehabilitation projects carried out by the government, the private sector, NGOs and community-based organizations.
b. Rehabilitation of degraded forests and lands.
c. Development of intercropping of food, herbal, medicinal, and/or horticultural crops under tree stands on degraded lands.

G. *Improvement of irrigation facilities and water conservation*

a. Conservation and rehabilitation of watersheds by reforestation, afforestation, and agroforestry systems.

b. Construction of small ponds, especially harvested rainwater-based reservoirs (*embungs*).
c. Establishment of efficient watering systems (small irrigation) based on *embung* for development of food, horticulture and fodder crops during the dry season.
d. Maintenance of *embung* catchment by reforestation, afforestation and agroforestry systems using cash crops.
e. Improving the use of natural water resources (springs, reservoirs and streams) efficiently, especially during the dry season.
f. Improvement and maintenance of small-scale irrigation systems.
g. Empowerment of local institutions in dryland water management.

H. Sylvi- and agropastoral development

a. Improvement of existing pasture management and animal husbandry techniques.
b. Renovation of existing pasture.
c. Developing non-grass fodder.
d. Research on the carrying capacity of pasture land.

I. Monitoring and evaluating climatic variation

a. Establishment of a complete weather station and database system.
b. Monitoring temporal climate variability.
c. Impact of climate variability and change to land degradation.
d. Impact of global phenomena such as *El Niño*.

J. Empowerment of local communities and local institutions

a. Facilitating the establishment of local communities and institutions.
b. Empowering existing local communities and institutions.
c. Recognizing traditional knowledge and wisdom.

K. Establishment of sustainable land management

a. Establishing demonstration plots of sustainable agriculture.
b. Transfer of knowledge and technology through regular field training.

L. Providing guidelines and manuals

a. Selecting appropriate guidelines and manuals.
b. Distribution of guidelines and manuals of appropriate technologies.

M. Creating and improving market systems

a. Improving infrastructure and facilities for dryland production, animal husbandry and forestry (especially non-timber product) areas.
b. Establishing partnerships and market networking.
c. Establishing market accessibility.
d. Establishing farmers' cooperatives.

Conclusion

The Ministry of Forestry of the Republic of Indonesia is the custodian for land degradation assessment at the national level. The assessment has focused on physical condition of the soil, such as soil loss, but not chemical properties of the soil. Degraded Indonesian land has been classified into highly (severely) degraded, degraded, slightly degraded and potentially degraded. Land classified as severely degraded and degraded is at an alarming stage and therefore it is targeted for the land rehabilitation programme and activities.

Participatory assessment should be carried out at the local level. When continuous data and maps of degraded land are made available periodically they should be regarded as early warning tools. One way to get local people to work together to stop land degradation is by promoting the GERHAN programme, in which the government provides free seedlings to let people plant trees.

Agrosilvipasture systems and *embungs* combat land degradation. They have been implemented successfully because irrigation and fertilization are not needed; they can be used on any landscapes and soils; they promote soil conservation, land rehabilitation, and environmental protection; and agrosilvipasture produces manure for other agricultural uses. Agrosilvipasture with multiple rows of legume trees provides substantial fodder for livestock throughout the year. Income from livestock and additional food crop production from this system can enhance community welfare and food security. The system can restore degraded land and conserve land and water resources.

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