Forest cover and land-use changes in Lao PDR according to the National Forest Reconnaissance Survey

Abstract

Lao PDR is located in the centre of Indochina with territory of 23 680 000 hectares and a population of 5.6 million people (in 2006). 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. According to the results of the last reconnaissance survey of forest cover in 2002, the total land area of Lao PDR covered by natural forest (canopy density of higher than 20 percent and height of above 5 metres) was 9 824 700 hectares or roughly 41.5 percent of the total land area, while the drylands (lowland dry dipterocarp forest) covered approximately 1 317 200 hectares or 13.88 percent of the total land area; almost all of this land area is located in the central and southern parts of the country.

In 1982 forest cover was 11 636 900 hectares or about 49 percent, in 1992 it was 11 168 000 hectares or 47 percent and in 2002 it was 9 824 700 ha or 41.5 percent. This shows a rapid decrease from 1992 to 2002 by 1 343 300 hectares or about 5.5 percent, while from 1982 to 1992 it was only 468 900 hectares or about 2 percent. The area of dry dipterocarp forest increased from 1 235 100 hectares in 1982 to 1 317 200 hectares in 2002 generated mostly by unsustainable harvesting or commercial logging.

It is planned to assess forest cover and land use from 2002 to 2012, which will reveal the current change of land use throughout the country. But it can be assumed that the area of dry dipterocarp forest will have been reduced due to the active conversion of this land category into commercial tree plantations (eucalyptus, acacia, rubber, etc.) and agricultural crop production (sugar cane, cassava, etc.), which is attributable to liberalized economic investment.

Currently there is no project for land degradation assessment in drylands in Lao PDR, but it is urgently needed.

1. Introduction

The Government of Lao PDR has recognized the incidence of land degradation since the establishment of the Lao People's Democratic Republic. The first step to combat land degradation was addressed in 1988 at the National Meeting on Transferring from Natural Crop Production to Commercial Economy. This meeting indicated that, in order to introduce commercial economic policy, the government would focus on land development. The meeting devised some measures for land management such as: (1) land development must be conducted in parallel with land conservation and should protect natural water resources, (2) land-use practices should avoid inducing land degradation and land erosion and (3) land development should not damage the natural environment.

In 1989 at the First Forestry Conference it was stated that "forest destruction in the country has reached a critical point; it is the time for us to change completely from indiscriminate logging and other forms of deforestation to focusing on tree planting and forest conservation" (Department of Forestry 1989).

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Forest cover and land-use change assessment from 1992 to 2002, which is part of the Forest Strategy 2020, addresses forest status, management and utilization of forest resources and land-use change throughout the country and provides the necessary information for drafting and implementing the Forest Strategy 2020.

From 2002 to date, there has been no further official assessment, but land development is likely to rapidly increase owing to commercial agricultural practices throughout the country, especially in the central and southern region, which is mostly flat and covered by dry dipterocarp forest and dryland that are highly sensitive to desertification.

2. Objectives

The main objectives of the National Forest Reconnaissance Survey entailed:

- Assessing changes in forest cover throughout the whole country from 1992 to 2002 in order to evaluate the status of forest management and use of forest resources;
- Providing necessary information for the formulation of forest strategy, policy and legislation;
- Drawing conclusions and defining the framework for future forest and land resource management.

3. Methodology

The survey consisted of two steps:

1. Plot sampling on Satellite Image Maps (SIMs) to detect the change of forest cover and land use from 1992 to 2002.
2. Field verification in order to identify the causes of changes.

3.1 Plot sampling on SIMs

Point sampling was carried out via SPOT satellite imagery dated 2001/2002 at 1:50 000 and 1:100 000 scales. In order to get further representation of all forest types and land-use categories, random sampling was designed.

3.2 Case studies

Case studies were conducted in 22 areas nationwide. The main objective was to detect the causes behind forest cover and land-use changes, including qualitative and quantitative changes.

4. Forest and land-use classification

Forest and land-use classification recognized current forest with canopy density of 20 percent and above, areas with canopy density below this threshold would be classified as other forest types.

5. Results of the sampling survey

In 2002 all forest cover areas with at least 10 percent and more of canopy density accounted for 71.6 percent (or 16 846 000 hectares) of the total land area, of which evergreen, mixed deciduous, dry dipterocarp and plantation forest comprised 41.5 percent, potential forest including secondary forest or old shifting cultivation areas, 2.2 percent and bamboo brakes, 2.3 percent; about 60 percent of temporarily unstocked forest (25.6 percent) could be naturally regenerated (see Table 1).

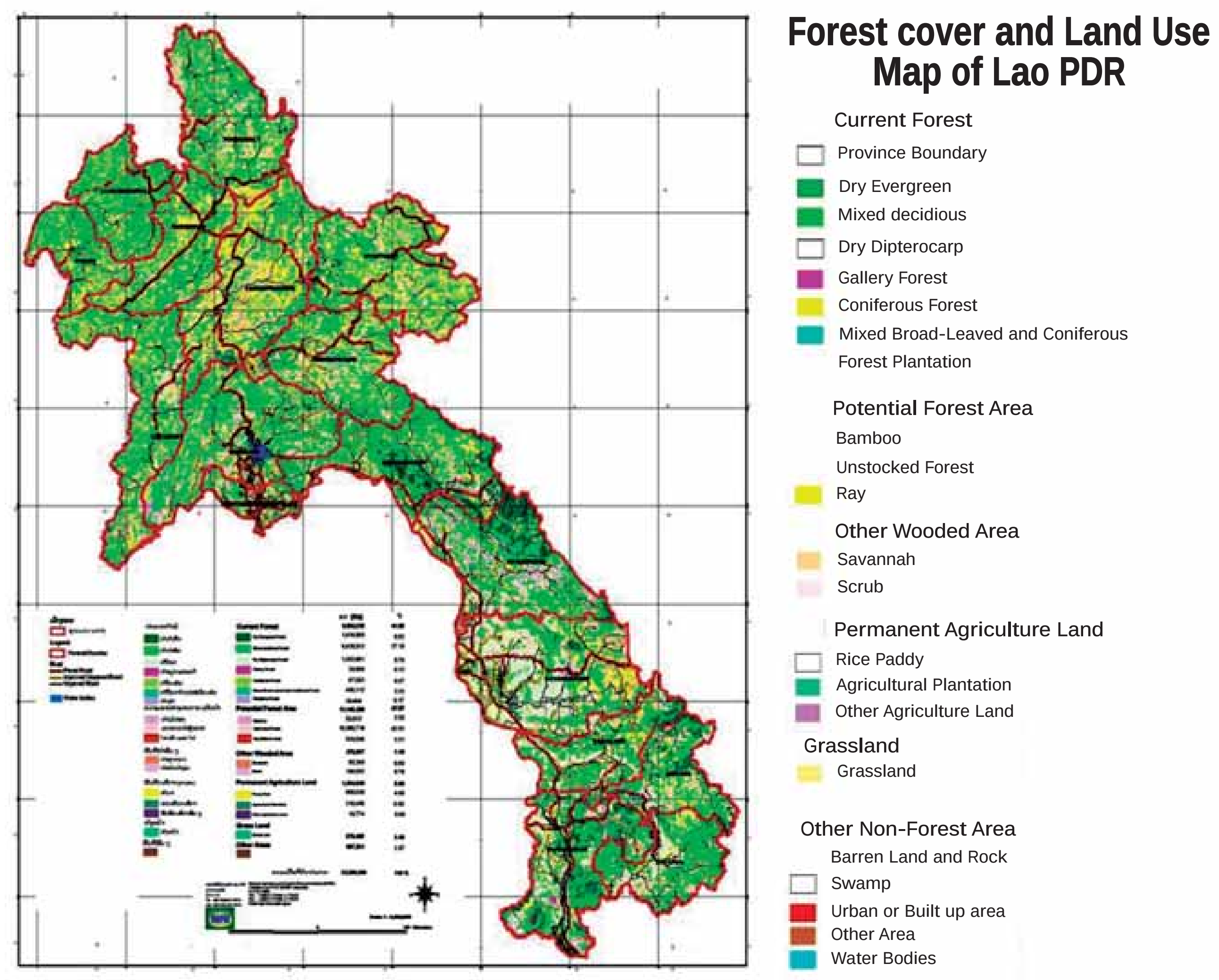

Figure 1. Forest cover and land-use map of Lao PDR

Table 1. Comparison of land-use groups and land-use distribution in 1982–1992–2002

Land-use group and land-use type	Distribution in %			Change in %		
	1982	1992	2002	1982–92	1992–02	1982–02
1. Current forest	**49.142**	**47.162**	**41.49055**	**-1.980**	**-5.672**	**-7.652**
Dry dipterocarp	5.216	5.095	0.563	-0.121	0.468	0.347
Lower dry evergreen	0.374	0.361	0.237	-0.013	-0.124	-0.137
Upper dry evergreen	4.670	4.481	5.861	-0.189	1.380	1.191
Lower mixed deciduous	3.771	3.651	3.720	-0.120	0.069	-0.051
Upper mixed deciduous	32.907	31.463	23.224	-1.444	-8.239	-9.683
Gallery forest	0.383	0.370	0.119	-0.013	-0.251	-0.264
Coniferous	0.584	0.557	0.376	-0.027	-0.181	-0.208
Mixed coniferous	1.237	1.184	2.221	-0.053	1.037	0.984
Tree plantation	–	–	0.169	–	–	0.169
2. Potential forest	**36.142**	**37.971**	**47.095**	**1.667**	**9.496**	**10.971**
Bamboo	6.153	6.469	2.276	0.316	-4.193	-3.877
Unstocked	27.448	28.680	42.636	1.232	13.956	15.188
Shifting cultivation area	2.523	2.642	2.183	0.119	-0.459	-0.340
3. Other wooded area	**6.526**	**6.098**	**1.210**	**-0.428**	**-4.888**	**-5.316**
Savannah/open woodlands	4.113	3.853	0.399	-0.260	-3.454	-3.714
Heath, shrub forest	2.413	2.245	0.811	-0.186	-1.434	-1.602
Sum of all forest area	**91.8**	**91.1**	**89.8**	**-0.741**	**-1.246**	**-2**

Table 1. *(continued)*

Land-use group and land-use type	Distribution in %			Change in %		
	1982	1992	2002	1982–92	1992–02	1982–02
4. Permanent agricultural area	**2.993**	**3.588**	**5.068**	**0.595**	**1.480**	**2.075**
Rice paddy	2.780	3.334	4.070	0.554	0.736	1.290
Agriculture plantation	0.063	0.075	0.916	0.012	0.841	0.853
Other agriculture land	0.150	0.179	0.082	0.029	-0.097	-0.068
5. Other non-forest area	**5.215**	**5.361**	**5.137**	**0.146**	**-0.224**	**-0.078**
Barren land, rock	0.464	0.490	0.976	0.026	0.486	0.512
Grassland	3.397	3.475	2.446	0.078	-1.029	-0.951
Urban land	0.347	0.356	0.571	0.009	0.215	0.224
Swamps	0.144	0.149	0.215	0.005	0.066	0.071
Water	0.863	0.891	0.929	0.028	0.038	0.066
Sum of all non-forest area	**8.208**	**9.949**	**10.205**	**0.741**	**1.246**	**2**
Total	**100**	**100**	**100**	**0**	**0**	**0**

The potential forest area (including bamboo brakes, unstocked areas used for shifting cultivation) had increased from 37.8 percent of the national area in 1992 to 47.1 percent in 2002. Within the potential forest area, unstocked area had increased from 28.7 percent in 1992 to 42.6 percent in 2002. This meant that unstocked forest area in 2002 was greater than current forest area (forest covered by 20 percent canopy, see Figure 2).

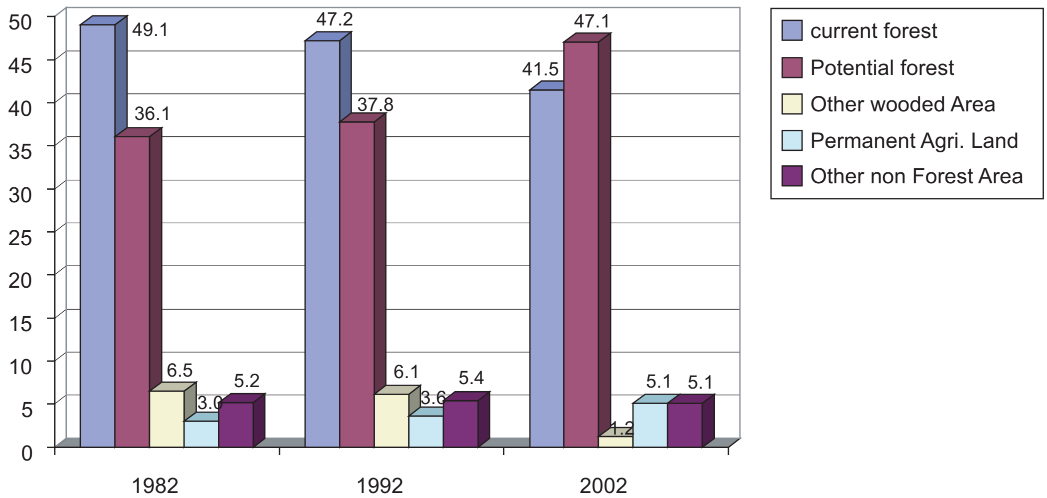

Figure 2. Changes in forest and land use during 1982, 1992 and 2002

However, as mentioned earlier, current forest area with more than 20 percent of canopy density was 41.5 percent (or -9.8 million hectares) in 2002 compared to 47.2 percent in 1992. By comparing change statistics for 1982 to 1992 and from 1992 to 2002, it can be seen that the rate of change of current forest was about 2 percent and 5.6 percent respectively and change during 1992 to 2002 was greater than change during 1982 to 1992 (see Figure 3).

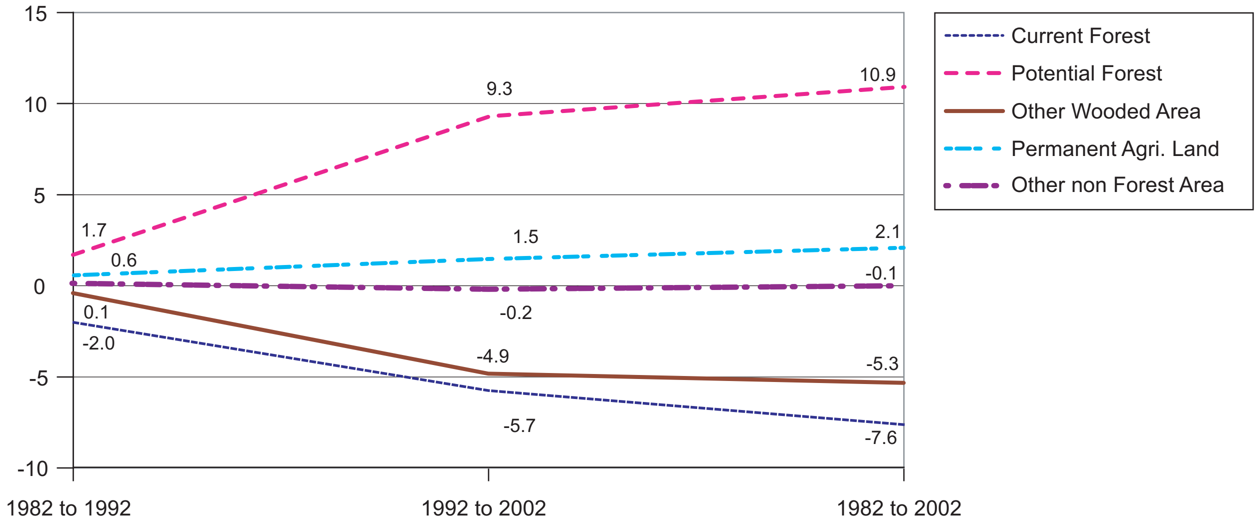

Figure 3. Comparison of the rate of forest cover and land-use changes

The study also compared forest cover and land-use change distribution in different regions of the country; it revealed that the change in forest area was quite extensive in the north compared to central and southern regions. In 2002, the current forest cover in the northern region was 27.9 percent or a reduction of 8.4 percent from 1992. Whereas, the current forest cover in the central region at that time was about 46 percent or a decrease by 5.7 percent during the same period. On the other hand, the current forest cover in the southern region was 56.5 percent, reduced by only 1.8 percent compared to 1992. Conversely, potential forest area was increasing in all regions. Forest cover and land-use changes by region during the last 20 years are illustrated in Figures 4, 5 and 6.

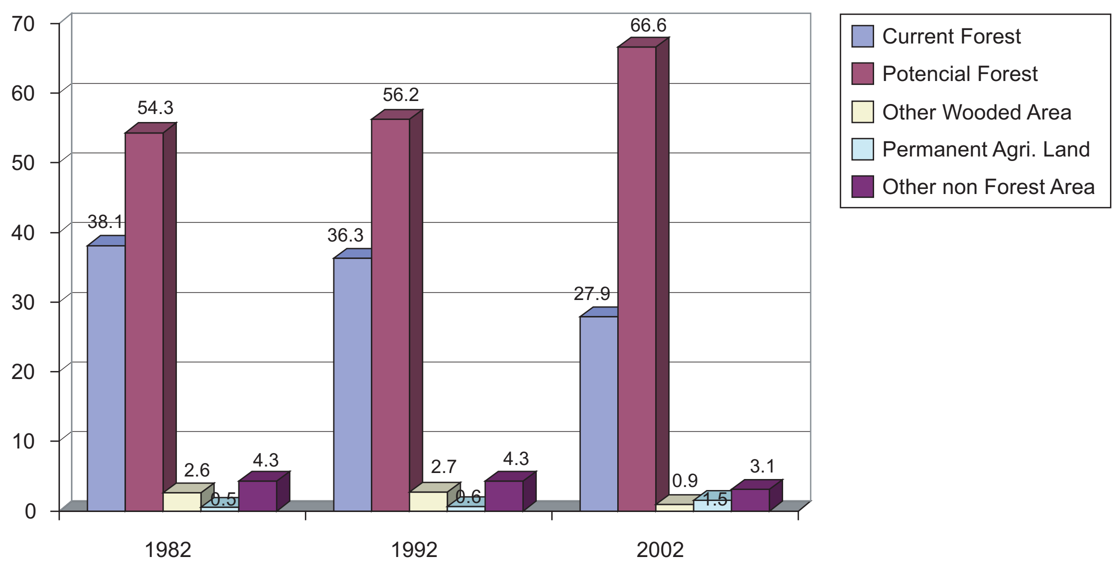

Figure 4. Forest cover and land-use distribution in the northern region

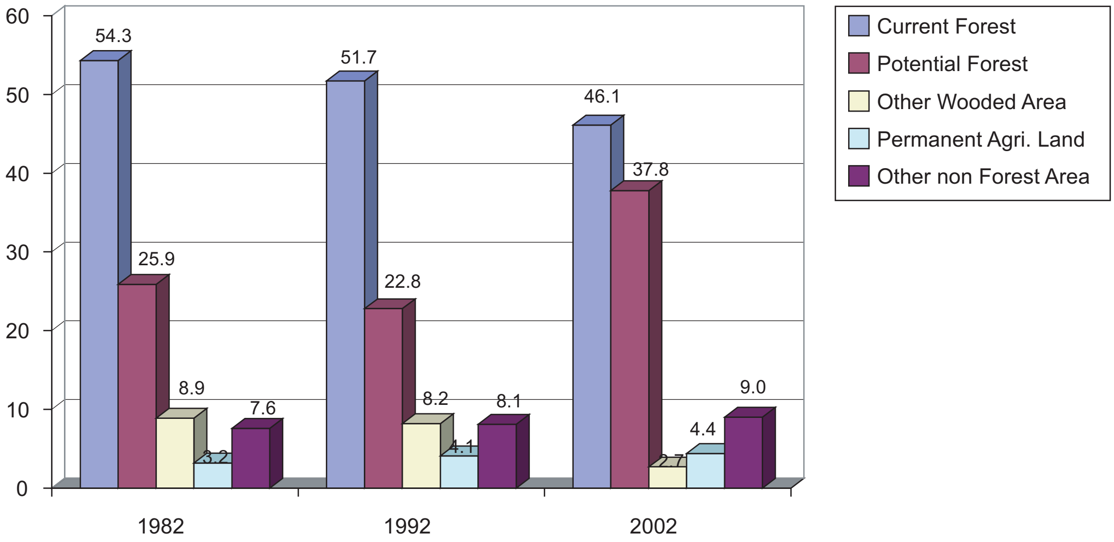

Figure 5. Forest cover and land-use distribution in the central region

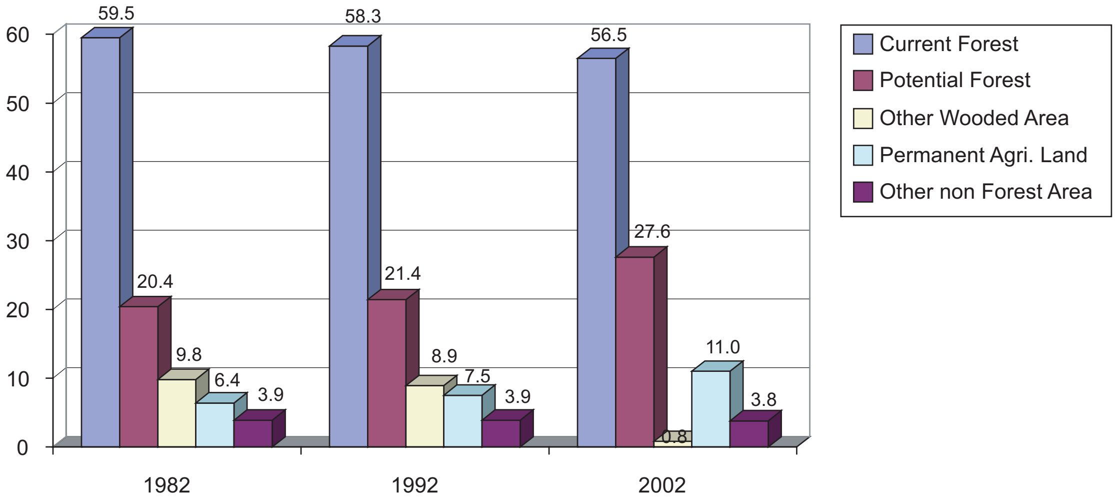

Figure 6. Forest cover and land-use distribution in the southern region

From Figures 4, 5 and 6, it can be seen that current forest cover in the northern and central regions changed quite rapidly compared to the southern region. The main reason behind this is the many conservation areas established in the south.

Shifting cultivation areas nationwide decreased from 2.6 percent in 1992 to 2.2 percent in 2002. At the regional level, however, the shifting cultivation areas in the north had slightly increased from 3.7 percent in 1992 to 4.1 percent in 2002, while in the central region they had declined from 2.1 percent in 1992 to 0.9 percent in 2002. Similarly, in the south, they had decreased from 1.6 percent in 1992 to 0.6 percent in 2002 (Figure 7).

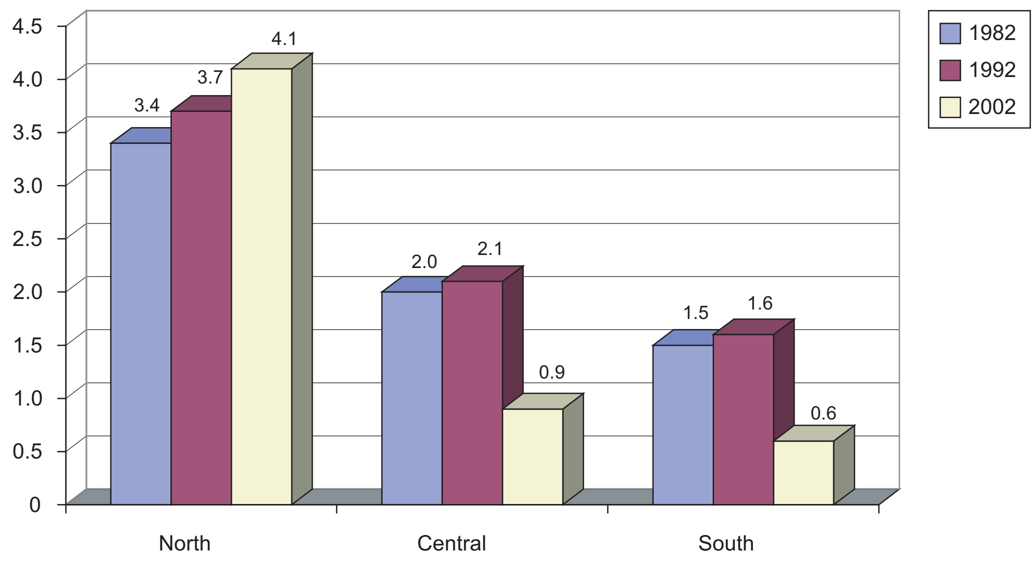

Figure 7. The percentage of shifting cultivation by regions

6. Factors behind forest cover and land-use changes

External factors

High demand for wood and non-wood forest products in wood-deficient markets in some countries in the region as well as the imposition of logging bans in neighbouring countries generated high pressure on forest resources in Lao PDR.

Internal factors

- Shifting cultivation practices and forest fires are still the main causes of forest and land degradation;
- Unsustainable harvesting of forest products, unsustainable management and use of wood by villagers;
- Conversion of forest land to permanent agricultural land and infrastructure development;
- Awareness raising and dissemination of laws and regulations among concerned agencies have not been fully effective and laws are not strictly enforced.

Underlying causes

The most basic factors are **widespread poverty and rapid population increase** among the rural population, who are, as a result, obliged to practise destructive forms of cropping resulting in deterioration and destruction of forest.

The second set of factors involved in forest cover decline relates to **economic incentives for overharvesting of forest resources**. For example, there are too many wood processing plants and excessive wood processing capacity has tended to put pressure on government bodies to grant harvest/logging plans in sizes and locations often not matched with available resources.

The third set of factors is related to **governance:**

- Public sector capacity to plan, supervise and control implementation of forest and land development is seriously limited, both in terms of number and specification of staff and availability of physical and budgetary resources;
- The legislative and regulatory framework is still in its early stages and as yet incomplete. Annual Implementation Prime Ministry Orders have been issued as gaps are noticed and efforts are being

made to address them with the support of international organizations, donors, international financial institutions and others;

- Land and forest allocation plays an important role in land-use stabilization. However, there is a lack of qualified staff, equipment and funds, which contributes to shortcomings in implementation.

7. Conclusion

The results of the study based on plot sampling, the parallel mapping exercise, case studies and field checks, lead to conclusions about forest cover, land-use changes and trends during the last 20 years.

The population, especially the rural population, has almost doubled during the last 20 years. The increasing rural population has put more pressure on rural areas through production of food and collection of fuelwood. There is also an increasing demand for construction materials such as bamboo and wood.

Despite the rising rural population the extent of shifting cultivation remains static for the north, but in the central and southern regions it has decreased slightly. (Naturally there are certain areas within those regions where shifting cultivation has increased, but this is not influencing the general trend.) The area of agricultural land has slightly increased all over the country, especially in the south.

During 1992–2002, the unstocked area increased annually at about 106 000 hectares in the central region and 73 000 hectares in the southern region on average. Therefore, shifting cultivation cannot be the reason for the increase to this extent. Because forest cover was reduced almost to the same extent as the unstocked area had increased, and the fragmentation of forest had increased too, the primary reason must be logging.

The rural population is responsible for the smaller fraction of logging for local consumption. Local fuelwood and construction material are collected near villages and along roads usually in already unstocked areas or abandoned logging areas. The public penchant for logging prefers very steep slopes along the roads because logs can be easily taken to the roadside. This is probably the main reason for many landslides along roads.

It is likely that illegal logging occurs as well, but the volume of forest loss and the decrease of unstocked area cannot be done illegally alone. It is the result of uncontrolled logging as indicated by some case studies. The domestic sawmill capacity is much greater than the annual allowable cut based on former forest cover data, which puts enormous pressure on forest resources. The logging bans in neighbouring countries and the local development demand also exert great pressure on the forests of Lao PDR.

There are many tree plantations along the roads and around villages. However, they are usually very narrow strips and immature. The field check clearly confirmed that these plantations are difficult to identify on SIMs. They are included in the unstocked area or in agricultural plantations.

The most forested areas are within the National Biodiversity Conservation Areas, supposed to protect the biodiversity of the country. The further deforestation of certain areas would increase the risk of natural catastrophe and would severely endanger the lives of the rural population, infrastructure, agriculture and other sectors, and ultimately the whole national economy.

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Land degradation assessment in the drylands of Myanmar

Abstract

Being an agriculture-based country, the national economy of Myanmar largely relies upon agricultural and forestry products. Thus it needs improved land for growing major crops, improved pasture and better forests. However, land degradation in any form of the drylands of Myanmar can be a major threat and challenge to the country's economy and dryland communities.

Introduction

Land degradation in Myanmar is caused by water erosion, wind erosion, soil fertility depletion, salinization, alkalinization and waterlogging. Visible land degradation is recognizable in the central dry zone area of Myanmar and extends partially over the Divisions of Mandalay, Magway and Sagaing covering 17 percent of the total area of the country. In these areas, soil erosion is intensive and rapid as a result of heavy rain showers and the low degree of rock compaction. Surface runoff has been estimated to be 30 percent (Bender 1983). Removal of the natural savannah vegetation quickly leads to erosion, which is most intensive at the start of the monsoon rains on bare soils. In the dry zone, where rainfall is already low, reduced infiltration means less effective utilization of precipitation. An increase of runoff also leads to the expansion of rill and gully erosion.

The main impact can be said to fall into the following categories:

1. The degradation of water quality and quantity, controlling water-related disasters.
2. The degradation of arable soil.
3. Fuelwood conditions.

Most of the watersheds under critical condition are found in the dry zone area. Soil erosion and land degradation are the two components responsible for declining production potential.

The characteristics of the central dry zone area of Myanmar are: semi-arid monsoon climate with erratic and low rainfall ranging from 650 to 750 mm, and a high range of temperature (minimum 12ºC to a maximum of 40–42ºC). Soil has been eroded to varying degrees. In some places the soil has been almost completely removed by water and wind erosion. Thus there is serious concern about the negative implications for the livelihoods of rural populations and the environment. This is exacerbated by overexploitation of natural resources fuelled by population pressure, unreliable climatic conditions and a fragile biophysical environment. In addition, poor management on cultivated and grazing lands cannot cope with increasing demands for food, clothing and other basic needs.

In central dry zone areas, indicators of land degradation are the rapid depletion of woody biomass, expansion of farming into marginal and steeper slopes, extensive and uncontrolled use of limited pastures in erosion-prone areas and increasing numbers of small livestock that can adapt to the deteriorating environmental conditions. All of these factors induce chronic poverty, irreversible environmental damage, recurrent droughts and increasing threats to food security. Soil erosion is severe in the upland area of Kyaukpadaung and Chaungoo as a result of high rainfall intensity and surface runoff. Moreover, the erodibility of the soil in these

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areas is also high as the soil is moderately textured, with slopes of 5–15 percent. Levels of land degradation were pointed out in three townships namely; Kyaukpadaund, Magway and Chaungoo in the central dry zone area, under the project MYA/96/006.

In the Kyaukpadaung area, the erosion problem is severe with 50 percent of the cultivated land losing its top horizon; this means that most of the fertile soil has been lost through severe sheet and rill erosion. Infiltration and the water holding capacity of these soils are limited. Erosion rates on cultivated land range from 50 tonnes/hectare/year for optimum soils on gentle slopes to 150 tonnes/hectare/year on slopes of 3–15 percent with sandy–loamy or sandy–clay–loamy soil. Many hillsides are almost bare, rocky, compacted and heavily crusted.

In the Magway area, there is a high level of erodibility, because of the sandy topsoil. Soil loss was estimated at 30 tonnes/hectare/year on better lands with gentle slopes (<3 percent) and over 75–100 tonnes/hectare/year on undulating lands with sandy loams, surface crusts and low water holding capacity.

In the Chaungoo area, the erosion problem follows the same pattern as Kyaukpadaung, mainly in the upper parts of township areas, showing similar severity and rates of erosion and runoff.

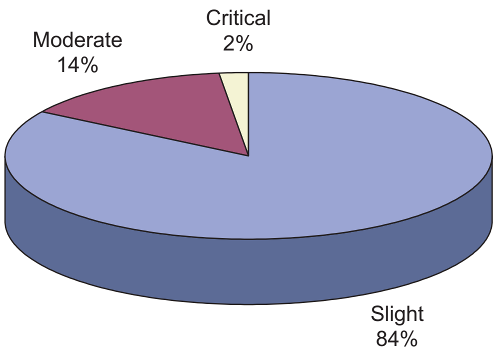

Figure 1. Erosion susceptibility conditions in the dry zone of Myanmar

Land degradation caused by water erosion is most extensive and visible. It was estimated that about 72 percent of the whole country is affected by water erosion. In this category, mountainous regions, the Shan Plateau and rolling and undulating areas of the semi-arid regions mainly in the central dry zone areas were assessed. Mountainous areas and the plateau lie at high elevations ranging from 700 to over 3 000 metres above sea level with high annual rainfall ranging from 2 000 to 5 000 mm and gradients ranging from 45 to 70 percent. High shifting cultivation activities accompanied by these factors make the land highly susceptible to water erosion. Only forest and vegetation cover can prevent total soil loss.

According to the Reconnaissance Soil Survey conducted by the Land Use Department 30 years ago, there were four types of water erosion. Their extent is shown in Table 1.

Table 1. Extent of water erosion

Type of water erosion	Extent
Slight rill erosion	7.2%
Slight to moderate rill and sheet erosion	38.2%
Severe sheet and gully erosion	26.2%
Topsoil completely removed	0.4%

Note: Total water erosion affected area = 72 percent (approximately).

Figure 2. Serious erosion in the dry zone area

Wind erosion effects are well recognized in the central dry zone areas for the following reasons:

- Light-textured Luvisols;
- Scanty rainfall and arid soils throughout the year;
- Unprotected crop fields, lack of natural forest barriers;
- Soil-loosening crops such as major oilseed crops predominate;
- Hot and dry winds suck away meager moisture stored in the topsoils.

About 11 percent of the total land area is affected by wind erosion, which occurs mainly in central dry zone areas that are economically important to the national economy.

Depletion of soil fertility is a serious problem in Myanmar as the most economically important soils of the country are found in these problem areas. It was estimated that about 12.3 percent of the total land area situated in the central dry zone faced depletion of soil fertility as well as soil nutrient imbalance. All the agricultural lands on Luvisols in central dry zone areas have depleted soil fertility generated by the following factors:

- Very light in texture (sandy loam to loamy sand);
- Too low in moisture and very high in temperature;
- Rolling and undulating and prone to wind and water erosion;
- Completely deprived of organic matter;
- Yearly cropping without any fertility improvement measures such as green manuring, composting and balanced fertilizer application.

Soil fertility depletion is also found in the Shan Plateau due to water erosion, high acidity and lack of soil improvement techniques. Since this degradation problem is a serious one, it needs to be addressed urgently.

Approximately 1.4 percent of the whole country is affected by both salinization and alkalinization that cause land degradation. Coastal strips, deltaic and arid regions are impacted by salinization while alkalinization is confined only to certain areas of the arid region. Types of soils under the salinization category are Gleysols and Vertisols, while Vertisols mainly occur in the alkalinization category. Salinization occurs in the coastal and delta regions due to seawater intrusion. Although heavy rainfall (over 4 000 mm) and flooded rice cultivation annually flush out deposited salts, high tides and high evapotranspiration in the summer make the soils more saline. Thus, the salinity effect is more harmful to dry season crops. Salinization in the central dry zone is mainly caused by saline groundwater evapotranpiration which results in salt crusts on the soil surface. Unfortunately, scanty rain is not enough to wash out the accumulated salts. In addition, using saline irrigation water causes salinization. Alkalinization also occurs in the same way in dry zone areas.

The area of land degradation due to waterlogging is smaller than other affected areas. Less than 1 percent of the total land area found in the Ayeyawady Delta Region is affected by waterlogging. Although the extent is small, waterlogging creates adverse effects because of its occurence in major rice production areas. Thus, the nature and extent of waterlogging need to be studied to develop preventive measures.

Practical methodologies

At present, the extent and locations of land degradation in Myanmar are mainly derived from aerial photograph interpretation and reconnaissance soil survey using topographic maps. From these maps, the severity of water erosion was deduced.

No comprehensive studies concerning the severity and extent of various forms of land degradation have been conducted because there has been no specific demand by any users for land degradation data in detail. Moreover, there are no means and financial resources to conduct a specialized study of land degradation at a national scale by the Land Use Division (LUD). In spite of this, LUD conducted a thorough examination of land degradation in the surveyed area during its normal detailed planning and classification of various degrees of land degradation according to international standards.

Mapping of degraded land, availability, scales and methods used

At present, mapping is carried out by the LUD. The three types of major maps produced are: agro-ecological zone maps, soil maps and soil erosion maps at the national level. Soil maps based on land topography are produced at the state/division level. Mapping is based on 16:1 scale, which is used by the Department of Settlement and Land Record, and 1:1, 1:2 and 1:4 scales for military maps. Data on the shifting cultivation area are produced using the Forest Inventory Maps generated by the Forest Department, Ministry of Forestry. Types of water erosion and their affected areas are deduced from medium-scale soil survey maps produced by LUD and the Myanmar Agriculture Service (MAS), Ministry of Agriculture and Irrigation (MOAI).

Geographic information systems (GIS) have been used recently for the production of soil maps to clearly explore soil degradation condition in central dry zone areas. The usage is unsophisticated due to lack of software as well as human resources and financial aid.

Prediction and modelling for land degradation development

Slope maps, which are essential for erosion mapping and land capability mapping, have never been produced in Myanmar for so large an area. The methodology has been contributed by the Watershed Management for Three Critical Areas Project. After the slope maps have been produced for the entire project area at 1:633 600 scale, algorithms to produce erosion susceptibility data are formulated using FAO procedures. Management practices that conserve soil moisture or increase soil water holding capacity of the soils employ soil conservation techniques.

For the time being, LUD is conducting measurement of the erosion rate on an experimental basis mainly in the central dry zone areas. Treatments include bare soil plots, contour plantation plots, plantation plots along the slope and natural vegetation plots. Soil loss findings from the tested plots are given in Table 2.

Figure 3. Fish-bone terraces in the dry zone (for soil protection)

Figure 4. Sediment storage dam in the dry zone (for soil protection)

Figure 5. Plantation of wind-break trees (for wind-erosion protection)

Figure 6. Tea plantation along contours in the hilly region of Northern Shan State

Table 2. Rate of erosion from different treatments

Testing period	Bare soil (no grass)	Plantation plots along contours	Plantation plots along slopes	Natural vegetation	Rainfall amount
26 June to 7 October 2007	0.63 t/ha	0.20 t/ha	0.22 t/ha	0.18 t/ha	3.8 mm to 2 mm in 17 rainy days with total rainfall of 200 mm

Conclusion

Land degradation has been a severe threat to sustainable agriculture and forest development for 50 years. Land degradation due to wind and water erosion, salinization and alkalinization is of particular concern. According to the current land utilization, about 11 million hectares or 16 percent of the total land area is under cultivation. Since a total of about 18 million hectares is estimated as suitable for agricultural purposes, some 7 million hectares of new land can be brought under crop cultivation and livestock farming. In bringing new land under agricultural use, it is important that scientific techniques for land evaluation and land-use planning are used to ensure the suitability and optimum use of land. In agricultural planning, land evaluation sets up a link between the basic survey of resources and the making of decisions on land use. As part of the land-use planning process, the Land Resources Information System is vital to ensure that environmentally valuable lands are not encroached upon and that adverse environmental impacts can be avoided.

To ensure conservation of the resource base, effective programmes should be designed to address the following constraints in agriculture:

- Low productivity due to agroclimatic conditions;
- Low productivity due to water shortage;
- Low productivity due to soil degradation, irrigation-induced waterlogging and salinity in the dry zone.

A number of agricultural research stations and centres are presently carrying out research on plant varieties, cropping patterns, irrigation techniques, water storage techniques and soil analysis. The programmes and activities of these centres should be reviewed to ascertain their effectiveness and to assist in the formulation of new programmes that can address key productivity constraints.

For the time being, only outdated aerial photograph interpretation and soil survey data (semi-detailed and topographic) are available, thus there is a need for improved methods to identify and collect more accurate information concerning the severity and extent of land degradation in Myanmar. Myanmar needs international cooperation and coordination among the network's countries for the establishment of a land degradation database, which will be of great benefit to land development.

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State of land degradation in the Philippines

Abstract

The Global Assessment of Land Degradation and Improvement estimated 13 200 hectares of degraded lands in the Philippines affecting some 33 064 628 million Filipinos. The quality and management of land resources in the Philippines has become a serious concern because of pressures of exponentially increasing population and subsequent need to expand agricultural production to marginal areas while ironically converting prime agricultural lands to non-agricultural uses. Accelerated erosion is the most common form of land degradation in the Philippines followed by nutrient mining and soil fertility decline. There are also problem soils such as acid soils, salt-affected soils and heavy-cracking soils. Intensive logging over decades and unsustainable agricultural practices on sloping lands are the major driving forces of land degradation. Two major maps are presented in this country report — Land degradation assessment: hot spots map*, which estimates degraded land areas to be around 5.4 million hectares, far higher than the Global Assessment of Land Degradation and Improvement study; and* Land degradation assessment: bright spot map, *which estimates equally fragile but non-degraded areas at 1.6 million hectares. These two maps will serve as input to the Land Degradation Assessment in Drylands (LADA) workshop for Southeast Asia. This is a Soil Information System-generated output based on soil erosion maps, slope maps and land-use maps with actual field data gathered from several decades. Currently, data updating is project-based and localized. However, the Bureau of Soils and Water Management (BSWM) updated its GIS and remote sensing facilities in 2008 through a World Bank loan under the Diversified Farm Income Development Project. It was able to acquire 36 scenes of 2007–2008 SPOT5 satellite imageries but a total of 234 scenes is required to cover the whole country. There are efforts to address land degradation in the country. On the policy side, agricultural zoning through the Strategic Agriculture and Fisheries Development Zones (SAFDZs) at the local government level and their integration into the Comprehensive Land Use Plan (CLUP) and proposals for enactment of a Soil Conservation Bill at the national level are among the major efforts. The BSWM is a focal point of the UN Convention to Combat Desertification (UNCCD).*

Introduction

Land degradation is a long-term decline in ecosystem function and productivity. It is increasing in severity and extent in many parts of the world — almost 20 percent of all cultivated areas, 30 percent of forests and 10 percent of grasslands. The Global Assessment of Land Degradation and Improvement showed that there are 33 064 628 Filipinos affected by land degradation. The total degraded land area is estimated at 132 275 km^2 (or about 13.2 million hectares). In the Philippines, it is estimated that soil erosion carries away a volume of soil equivalent to 1 metre depth over 200 000 hectares every year. As for soil fertility losses, the World Bank in 1989 estimated that the annual value of on-site fertility losses due to unsustainable upland agriculture in the Philippines to be around US$100 million, equal to 1 percent of Philippine GDP per year.

The quality and management of land resources in the Philippines have become a serious concern because of pressures of exponentially increasing population and the subsequent need to expand agricultural production to marginal areas while ironically converting prime agricultural lands to non-agricultural uses. Population increases and limited land resources are the two most important driving forces of land degradation.

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The annual growth trend of the Philippine population stood at around 2 percent in the first half of the twentieth century, surging in the 1950s and reaching a maximum of 3 percent in the 1960s. The growth rate gradually declined in the following two decades but has lingered at just above the 2 percent level since then. The 2000 Census placed the Philippine population at about 76.5 million. The National Census Office projects the Philippine population to reach 105.5 million by 2020. The population growth rate for the Philippines is still high by regional standards and this extends and accentuates the country's limited resources to accommodate such population increases. The unskilled and poorly educated move widely into public lands; in many cases the land's absorptive capacity cannot cope with the numbers involved.

The total land area of the Philippines is placed at 30 million hectares. A total of 15.8 million hectares are classified into forest lands; 14.2 million hectares are classified as alienable and disposable lands out of which about 13 million hectares are devoted to agriculture, 6.1 million hectares being highly suitable for cultivation. Agricultural areas are distributed as follows: (1) food grains occupy 4.01 million hectares, (2) food crops utilize 8.33 million hectares, while (3) non-food crops occupy 2.2 million hectares. For food grains, the average area for maize is 3.34 million hectares while for rice this is 3.31 million hectares. For food crops, coconuts account for the highest average at 4.25 million hectares, followed by sugar cane with 673 000 hectares, industrial crops with 591 000 hectares, fruits with 148 000 hectares, vegetables and rootcrops with 270 000 hectares, pasture with 404 000 hectares and cutflowers with 133 hectares. Land shortage and poverty, taken together, lead to non-sustainable land management practices such as clearing of forests and shifting cultivation and eventually low productivity.

This paper attempts to assess the extent of land degradation in the Philippines as input to the regional Land Degradation Assessment in Drylands (LADA) workshop for Southeast Asia.

Agricultural geography

The Philippines is an archipelago and along with this fragmentation comes divergent development that reflects local resource potential and varying social and political agendas.

The agricultural economy of the Philippines is reflective of a complex mix of several cropping systems, numerous land control systems, localized labour systems and differentiated trade, exchange and consumption systems (Gultiano *et al*. 2003). Several systems date back to the earlier centuries of European contact. Shifting agriculture is still extant. Five crops form the base for all regional patterns of agriculture in the country: rice, maize, yams, sweet potatoes and bananas, supplemented by coconuts as an enduring cash crop. Regional specialization results in one or more other crops being added to the rice–banana base and when agglomerated can constitute significant hectarage.

Rice is the traditional crop and central to the rural agricultural economy, covering almost half of the cultivated area. It is the staple food for almost three-fourths of the population. The Central Plain of Luzon is the largest regional producer. Southwestern Luzon, Eastern Panay and the Bicol Peninsula are important production areas. Islands such as Bohol, Leyte and the Cagayan Valley form secondary production areas. Most rice farms produce one crop per year in the wet season, especially where irrigation is deficient or non-existent. Rainfall is collected on the land through the provision of bunds or small dykes. The risk of water deficit is high and rainfall variability can have a marked effect on yield on a year-to-year basis. Two crops of rice can be produced in areas with irrigation technology. Rice is grown on approximately 2.3 million hectares of which 850 000 hectares are irrigated and planted at least twice or sometimes three times a year. Thus, the effective rice area coverage is placed at 3.15 to 3.31 million hectares.

Maize was introduced to the Visayas island group in the sixteenth century and has subsequently become an important crop. It grows reasonably well in slightly drier environments surrounding lowland rice fields or on hill slopes. It has gained regional dominance where rainfall is sporadic and wet seasons can fail with some regularity, also where soils and slopes are conducive to maize rather than to rice. Cebu Island is an example with its steeply sloping lands and limestone soils. Much of Mindanao is also conducive to its cultivation with its mountainous terrain and limited lowlands and lack of a wet rice tradition. Maize can be grown anywhere in the country but is quite limited to the rainy season in areas with more seasonal rainfall. Both white and yellow maize are grown. A primary maize-producing area surrounds Davao Gulf in southern Mindanao. A number of secondary production areas include the Cagayan Valley in Luzon, the Batangas Peninsula in Southwest Luzon, the Sorsogon Peninsula of southeastern Luzon, Eastern Panay Island and a wide area of western Mindanao. In the immediate post Second World War era, the country was self-sufficient in maize. But from the 1970s onwards as more maize has been channelled to livestock feeds than to human consumption, deficits have occurred and imports have increased.

The nature of land degradation in the Philippines

Accelerated water erosion. The most common type of land degradation in the Philippines is soil erosion. The loss of protective cover through deforestation and unsustainable upland agricultural systems make the topsoil vulnerable to removal with water runoff after a rainfall event. Erosion soil losses are much faster than on new soils that can be formed from weathering of parent materials. Once the nutrient-rich topsoil is gone, the area is unable to support plant life. This creates a cycle of poverty, resource exploitation and underdevelopment. As the land becomes increasingly degraded and thus, less productive, subsistence farmers are forced to illegally open up forest lands and overuse existing uplands leading to further land degradation.

Various degrees of soil erosion have been mapped and are summarized in Table 1.

Table 1. Area distribution of erosion classes by island groupings (million hectares)

Island grouping	Erosion class										Total	
	None (e0)		Slight (e1)		Moderate (e2)		Severe (e3)		Unclassified*			
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Luzon	4.1	57.7	4.1	46.6	4.1	48.2	1.7	32.7	0.2	50.0	14.2	47
Visayas	1.2	16.9	1.7	19.3	1.5	17.0	1.1	21.2	0.1	25.0	5.6	19
Mindanao	1.8	24.5	3.0	34.1	2.9	34.1	2.4	46.1	0.1	25.0	10.2	34
Philippines	7.1	23.7	8.8	29.4	8.5	28.3	5.2	17.3	0.4	1.3	30.0	100

Source: BSWM (1993).

* Unclassified erosion refers to quarry, river wash and open pit mines.

Nutrient mining and soil fertility decline. Soil fertility decline, directly or indirectly associated with fertilizer application, is also beginning to cause concern. Reports of organic matter depletion and issues relating to negative soil nutrient balance as well as onset of secondary and micronutrient deficiencies have emerged. There is a declining trend in productivity even with mineral fertilizer applications under modern intensive farming methods. A more realistic appraisal of soil fertility status in the Philippines needs to take account of how farmers dynamically manage their soils across their fields and crops and over the years. The dynamic status of nutrient management at the farm level is at the crossroads currently.

The green revolution of the mid-1960s was characterized by government investments in irrigation systems and modernization of agriculture through the use of high yielding varieties, inorganic fertilizers, chemical pesticides and other synthetic chemical inputs like the use of antibiotics and growth hormones in the livestock sector. Since then, Philippine agriculture had become predominantly conventional by the 1980s. The general trend based on soil analysis between the 1970s and 1990s indicated very active soil mining resulting in increased fertilizer inputs to sustain farm productivity. The period 1960–1970 was characterized by the need to use nitrogen (N) fertilizers only. The succeeding decade of 1970–1980 required higher phosphorus (P) fertilizer inputs in addition to nitrogen to maintain yield. The years 1980–1990 required not only N and P fertilizers but also increased potassium (K) plus micronutrients such as zinc for rice and magnesium for maize. The excessive use of urea fertilizers beyond the normal ratio of 3N:1P contributed to the stagnation of rice and maize yields and nutrient imbalance in the soil (Table 2).

Table 2. Yearly trend and ratio of N, P and K utilization (in tonnes per year)

Year	N	P	K	Ratio (N/P)
1980	224 866	53 784	55 782	4.18
1981	209 875	51 163	60 620	4.10
1982	232 840	56 139	57 435	4.10
1983	244 179	54 784	64 496	4.46
1984	180 569	45 372	38 617	3.99
1985	205 364	42 822	35 060	4.80
1986	298 323	42 771	46 267	6.97
1987	371 925	63 340	48 661	5.87
1988	372 118	77 471	54 934	4.80
1989	375 940	84 101	77 260	4.47
1990	394 767	46 188	68 512	8.55
1991	292 483	30 397	54 197	9.62
1992	331 537	36 025	61 628	9.20
1993	395 183	42 473	93 331	9.30
1994	396 751	46 920	38 944	8.46
1995	389 295	56 817	59 098	6.85
1996	462 776	65 055	90 346	7.11
1997	541 112	65 253	93 331	8.29
1998	408 778	53 299	81 740	7.67

By 2005, there had been a major shift in government policies owing to accelerated increases in the prices of farm inputs beyond the reach of ordinary farmers and a host of other issues like land degradation, climate change and biodiversity decline. Executive Order 481 was issued by President Gloria Macapagal Arroyo on 27 December 2005 to promote and develop organic agriculture as a farming scheme and to regulate the organic certification procedures. This was a significant milestone in the Philippine agricultural production policy as we refocused on our natural resources rather than on external resources with which to establish our agricultural production systems. The national government recognized that farming methods that neglect the ecology of soil, crops and nature damage the farming environment and are inimical to national interest.

Problem soils. The **heavy cracking clays** are land areas with 30 percent or more clay to at least 50 cm from the surface. These are Vertisols and are further classified as Uderts and Usterts comprising a total land area of about 766 388 hectares or 2.6 percent of the total land area. **Acid soils** or marginal lands belonging to Ultisols are found on undulating to rolling plateaus, hills and mountain areas extending to a total of 12 067 994 hectares. Oxisols comprise about 26 320 hectares. **Saline** and **sodic soils** are found mostly in coastal areas and total about 400 000 hectares or 1.33 percent of the total land area. **Poor drainage soils** or land areas waterlogged or flooded for significant parts of the year are classified as Fluvaquents (12 800 hectares) and Hydraquents (78 080 hectares) and are associated with Tropaquents, comprising about 0.30 percent of the total land area. **Coarse textured soils** are land areas with less than 18 percent clay and more than 65 percent sand or gravel stones, boulders or rocky outcrops in the surface layer. They belong to Tropopsamments along with other skeletal phases of other great soil groups, extending to about 482 849 hectares or 1.61 percent of the total land area.

Primary causes of land degradation

Intensive logging over decades. Forest cover in the Philippines decreased from 34 percent in the 1970s to 22 percent in 1987; the remaining forest cover is concentrated in Palawan, Mindanao and the uplands of Luzon. The last forest resource inventory in 1987 showed forest cover of 6.6 million hectares, leaving 10.8 million hectares of possible degraded forest land out of the 17.4 million hectares of designated forest land (>18 percent slope). Estimates and distribution of actual area in degraded open brushlands and grasslands are highly variable. Most of the area is mountainous and faces severe erosion problems with vegetation removal.

The underlying causes of deforestation are rooted in a complex web of social, economic and institutional problems both within and outside the forestry sector (Dent 1999). These problems include the combined effects of poverty, skewed land distribution, insecure land and tree tenure, low agricultural productivity and rising population pressure and increasing demand for forest and agricultural products. About 20 million people live and depend on the forested uplands. Declining wood availability, heavy soil erosion and flashfloods have led to logging bans on primary forests with concessions reduced to a few sustainable operations and massive reforestation efforts in the last few decades. The cutting down and the burning of trees and grasses and basic slope cultivation without soil conservation practices have resulted in land degradation.

Unsustainable agricultural practices in the sloping uplands. Upland land degradation results from intensification of agricultural land use without compensating investments in soil conservation and fertility. A major causal factor is upland migration. The land degradation rates dramatically increase by intensification of agricultural activities leading further to land-use pattern changes. Average annual soil loss by crop in the Philippines estimated by Coxhead and Shively (1995) is given in Table 3.

Table 3. Soil loss for various land uses and slopes (tonnes/ha/year)

Land use	Slope category	
	18–30	>30
Rice	50	100
Maize with fallow	50	150
Other agriculture	25	50
Forest	1	1

Poverty of the upland dwellers and their unsustainable farming methods have caused the deterioration of forests that contain valuable watersheds. Most of these upland and hillyland residents live on subsistence farming and lack access to basic services.

Policy-induced land degradation. Conversion of prime agricultural lands to urban and industrial uses is related to inadequate planning, poor implementation of zoning laws and increased population accelerated by rural-to-urban migration arising from failures in the development of rural economy and subsequent increase in poverty. The absence of a comprehensive land-use policy and the non-enforcement of such laws create inefficiency and improper land utilization. The lack of a rational, comprehensive and updated national and local land-use plan means that boundaries between forest lands and the alienable and disposable lands for agriculture, human settlements, industry, agriculture and other important land uses are not clearly delineated. This results in conversion of prime agricultural land to non-agricultural uses, displacement of rural communities and entry of commercial establishments in some ecologically fragile lands. In the Philippines, it is estimated that about 24 000 hectares of prime agricultural lands are lost per year due to conversion of farms to urban and industrial development.

Currently there are efforts to address this issue aside from efforts in the legislative body to enact a Land Use Act for the country. Under the Republic Act 8435 known as the Agriculture and Fisheries Modernization Act, the law provides delineation of SAFDZs within the Network of Protected Areas for Agriculture and Agro-Industrial Development to ensure that lands are efficiently utilized for agricultural production and agro-industrialization. Crop and livestock production zones are considered non-negotiable for conversion. These include irrigated lands, irrigable lands already covered by irrigation projects with firm funding commitments and lands with existing or potential for growing high value crops. If ever, only 5 percent of SAFDZ area may be converted. The law requires local government units to integrate SAFDZs into their CLUP.

The Philippines has yet to enact a Soil Conservation Act. The BSWM and the rest of the scientific community on resource management are lobbying for the sponsorship of a bill and its eventual enactment into law.

Assessment of land degradation

National-level scale assessment. A major output of the third JICA–BSWM technical cooperation (2001–2005) is the development of the Agricultural Resources Information System (ARIS) which integrates the earlier completed Soil Information System (SIS) and the Land Resources Information System (LARIS). The LARIS includes related socio-economic information for economic suitability analyses. Added to ARIS is the Water Resources Information System which basically caters to the databank holding of Small Scale Irrigation Projects being handled by the BSWM. ARIS is a data bank and decision-support system to provide instantaneous land suitability assessment, evaluation or analysis based on soil morphological, physical and chemical properties as well as the agrosocio-economic elements of land management units. The ARIS framework consists of data, query and model subsystems.

Under the query system and using ArcGIS® 9.3, a check on the 'moderately and severely eroded areas' in the Philippines is presented in Figure 1. The pink mapping units are moderately eroded areas while the red mapping units are severely eroded.

The erosion data are overlaid with slopes greater than 30 degrees and additionally overlaid with land-use maps to cover the following classifications: cultivated areas, grasslands, open canopy, arable lands, croplands with coconuts, croplands with other crops, coconut plantations and other plantations. The results are presented in Figure 2.

The computer-assisted estimation on the area coverage of land degradation hot spots is summed up in Table 4.

Table 4. Land degradation hot spot coverage via computer-assisted estimation

Region	Area (hectares)
ARMM	104 721.14
CAR	597 028.67
CARAGA	311 791.88
REGION I (ILOCOS REGION)	363 363.78
REGION II (CAGAYAN VALLEY)	538 458.07
REGION III (CENTRAL LUZON)	221 223.40
REGION IV-A (CALABARZON)	238 153.84
REGION IV-B (MIMAROPA)	350 052.45
REGION IX (ZAMBOANGA PENINSULA)	167 433.48
REGION V (BICOL REGION)	160 569.55
REGION VI (WESTERN VISAYAS)	383 826.29
REGION VII (CENTRAL VISAYAS)	446 037.73
REGION VIII (EASTERN VISAYAS)	362 123.02
REGION X (NORTHERN MINDANAO)	409 467.04
REGION XI (DAVAO REGION)	417 666.44
REGION XII (SOCCSKSARGEN)	295 130.22
Total	**5 367 046.98**

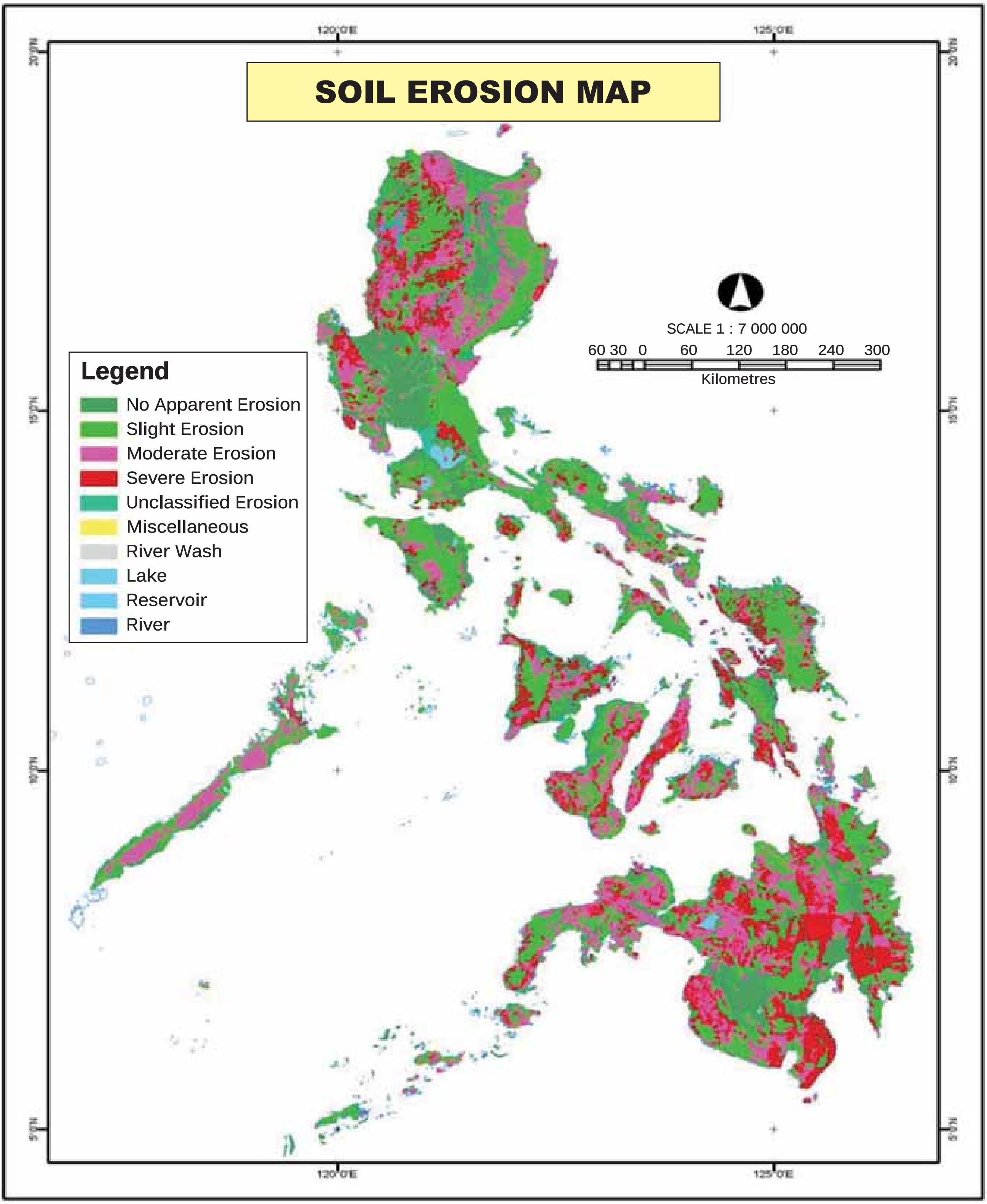

Figure 1. Soil erosion map of the Philippines

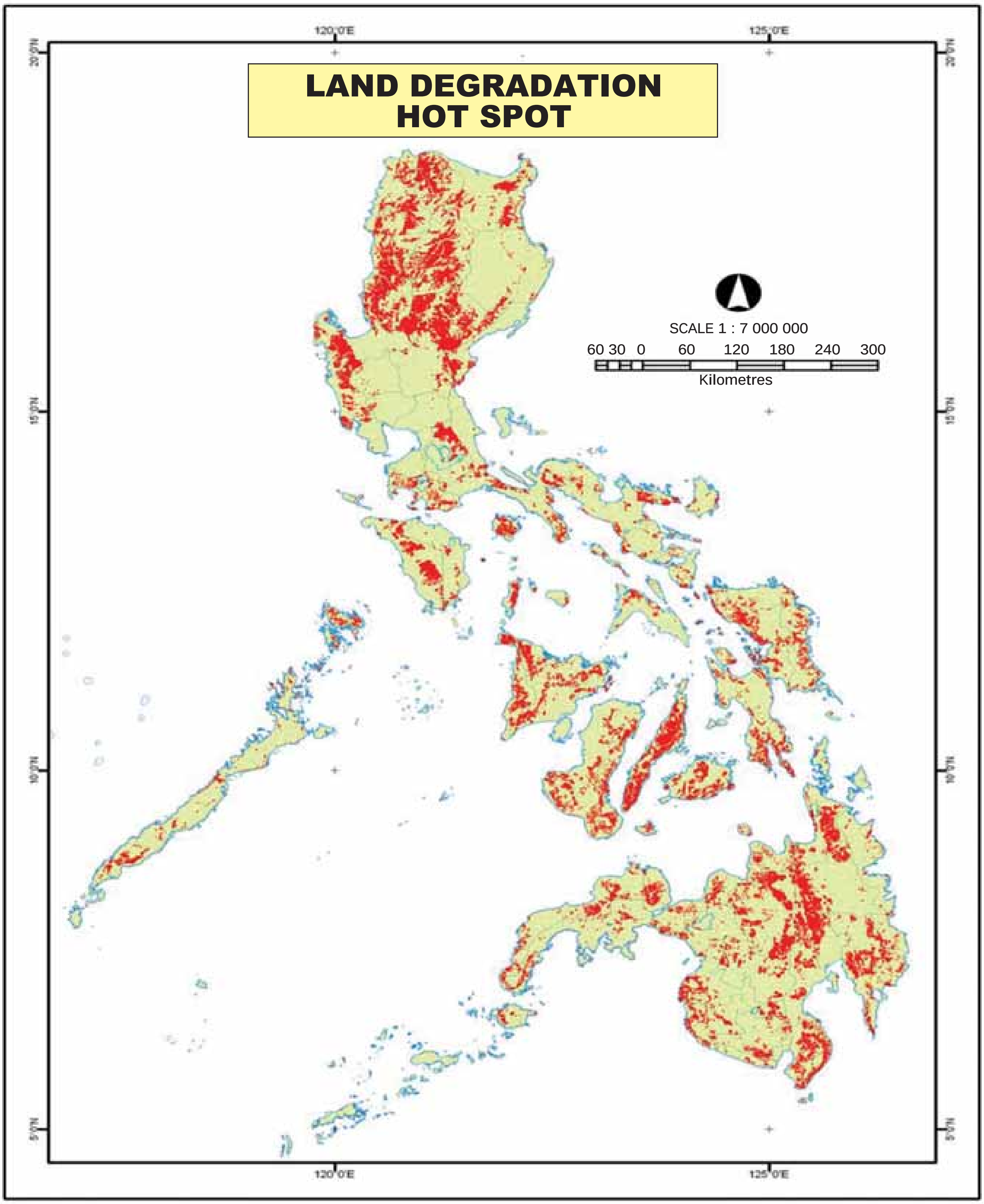

Figure 2. Land degradation hot spots in the Philippines

It can be seen that the BSWM estimate for *land degradation hot spots* is about 5.4 million hectares, far higher than the Global Assessment of Land Degradation and Improvement study of 13 200 hectares. This is more representative of the Philippine scenario as it includes areas outside the mandate of the Department of Agriculture. This is a summary of several decades of BSWM efforts to assess the state of land degradation in the country. Owing to the cost considerations to update the data, there has not been a more recent field validation of the national data set except for scattered project-based field surveys to be discussed later.

Another query of the ARIS data set checks on the 'none to slightly eroded areas' given the same parameters in terms of slope and land use, except for open canopy and cultivated areas. Figure 3 presents the bright spots of land degradation in the Philippines.

The computer-assisted results are summarized in Table 5.

Table 5. Land degradation bright spot coverage via computer-assisted estimation

Region	Area (hectares)
ARMM	15 345.32
CAR	242 293.98
CARAGA	91 157.75
REGION I (ILOCOS REGION)	55 764.90
REGION II (CAGAYAN VALLEY)	135 040.74
REGION III (CENTRAL LUZON)	131 069.68
REGION IV-A (CALABARZON)	168 144.11
REGION IV-B (MIMAROPA)	110 973.88
REGION IX (ZAMBOANGA PENINSULA)	64 757.00
REGION V (BICOL REGION)	47 100.69
REGION VI (WESTERN VISAYAS)	78 077.63
REGION VII (CENTRAL VISAYAS)	17 794.68
REGION VIII (EASTERN VISAYAS)	145 725.34
REGION X (NORTHERN MINDANAO)	107 578.30
REGION XI (DAVAO REGION)	91 351.26
REGION XII (SOCCSKSARGEN)	91 996.71
Total	**1 594 171.97**

About 1.6 million hectares of fragile hillylands and mountainlands can be considered as bright spots. Despite agriculture in these ecologically fragile areas, they show absence of land degradation.

State of BSWM GIS and remote sensing facilities for land degradation assessment. Although the maps and figures presented here represent more than three decades of BSWM land degradation assessment, this does not mean however that BSWM would have to resort to direct field survey methodology again to update its data. It took BSWM more than 30 years to complete its soil resources' assessment of the whole country. Considering the current demand for primary data, BSWM is more than ready to take the challenge.

Its GIS and remote sensing facilities were upgraded through a World Bank loan under the Diversified Farm Income Development Project in 2008. Both hardware and software were upgraded. BSWM's GIS and remote sensing laboratories have the capability to build on information layers for land degradation assessment by overlaying on the erosion map other land degradation parameters such as flooding, salinity, rock outcrops, etc. and come up with a separate GIS-based land degradation information system as a subcomponent of ARIS. Staff development is continuing, in fact, one GIS junior scientist is pursuing a Ph.D. in Australia. BSWM is also an active participant in the Department of Science and Technology — the lead consortium on the Science and Technology Coordinating Council–Committee on Space Technology Applications (STCC–COSTA). Our Remote Sensing Specialist, Ms Juliet Manguerra, attended the International EOS/NPP Direct Readout Meeting

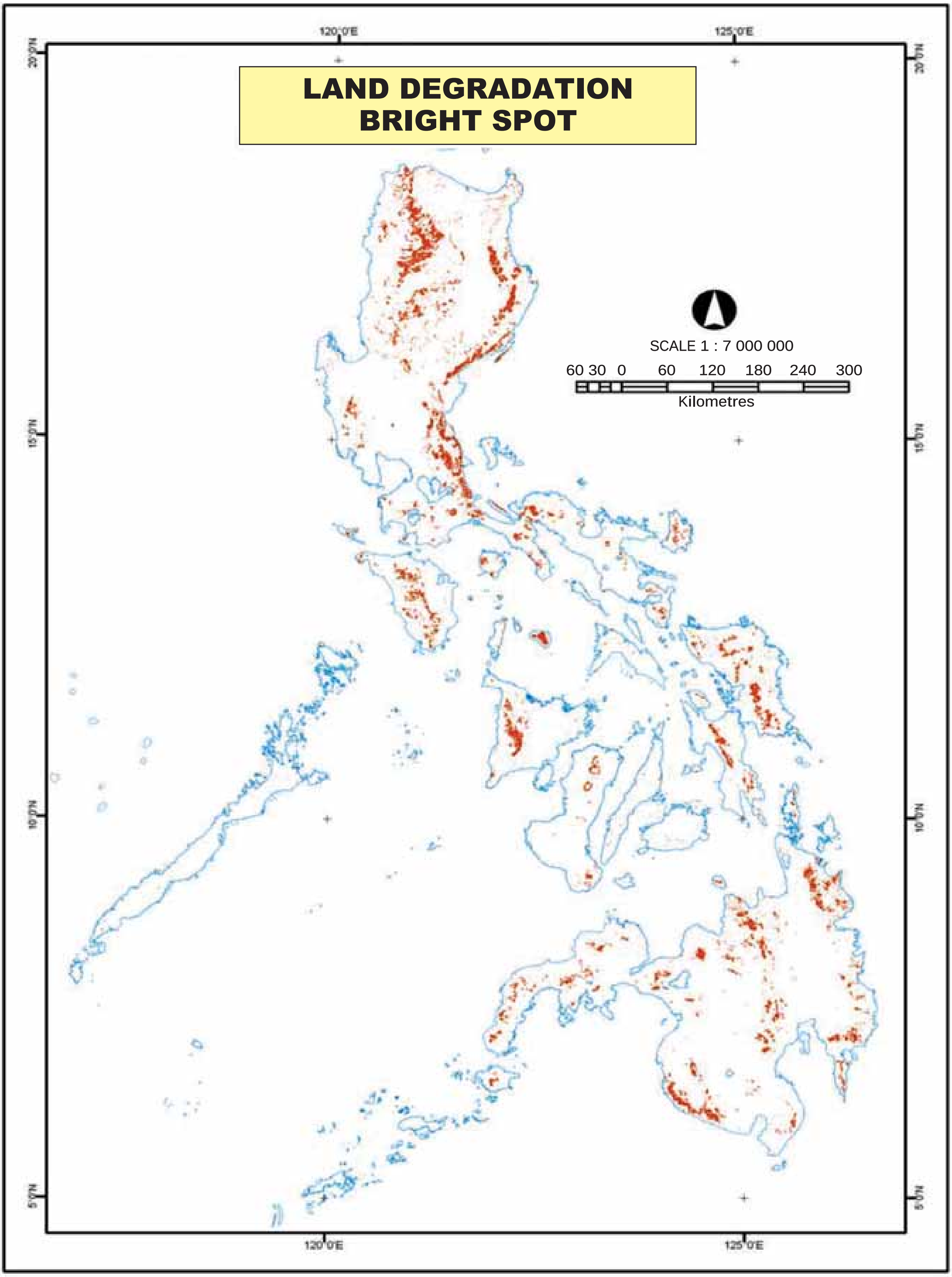

Figure 3. Land degradation bright spots in the Philippines

in Bangkok in March 2008 sponsored by the National Aeronautics and Space Administration, the Asian Institute of Technology, the Geo-Informatics and Space Technology Development Agency, the United States Department of Agriculture (USDA) Forest Service and the University of Wisconsin for the development and utilization of scientific algorithms for real-time and temporal applications. Her poster paper is reproduced as Figure 4 to show BSWM's capability in the use of satellite imageries for agricultural resource evaluation.

The major limitation of BSWM in coming up with updated land degradation assessment is the high cost of satellite imageries to cover the whole country. Its recent 2008 SPOT5 acquisitions consisted of only 36 scenes acquired at the cost of PHP5 million (US$1.00 = PHP47.8, September 2009) and it would take 234 scenes to cover the entire country. Our complete set of multitemporal satellite imageries is MOS-1 MESSR covering the period 1987–1995 in four wavelength bands in the visible and near infrared regions. The high cost of the acquisition of real time and multitemporal satellite imageries represents a major setback in our updating activities.

Much of the updating of land degradation status is on per-project basis. Through ARIS, the project scale updates are automatically inputted in the national soil and land resources data warehouse.

Project-level scale assessment. Currently, updated land degradation assessments are normally conducted at project-level scale. For instance, about 32 municipalities have been assisted in the mapping of their SAFDZs for integration to CLUP. For this year, BSWM is involved in the SAFDZ–CLUP integration of two provinces and one city. This has enabled BSWM to conduct detailed soil and land resources' assessment and evaluation, determine land limitations to agricultural productivity and thereby assess also the state of land degradation. Examples presented here are the soil erosion map (Figure 5) as well as the slope map (Figure 6) of Iligan City.

There are also watershed-level projects dealing with soil conservation where equally detailed land degradation assessments are conducted. One example is the Inabanga Watershed, Bohol Project for sustainable soil and water resource management collaborating with the Australian Centre for International Agricultural Research. A comprehensive GIS-based soil and water resource data set, which included agrosocio-economic issues, provided a rich source of information to support better decision-making, trend evaluation and modelling. Cropping, land-use suitability and the state of land degradation were assessed in the different pedo-ecological zones within the watershed.

The JICA–BSWM technical cooperation on the environment and of productivity management in selected acid soils in the provinces of Bukidnon, Rizal and Bulacan also provided updated and detailed land degradation assessment. The outputs are similar to SAFDZ–CLUP integration projects but at the watershed level rather than the municipal level.

The Philippines National Action Plan

BSWM is the Philippine Focal Point of the United Nations Convention to Combat Desertification (UNCCD). A major input in the preparation and updating of the National Action Plan (NAP) is assessment of the state of land degradation.

The Philippine NAP (2008–2018) is still under revision in time for the Ninth Conference of the Parties, October 2009. The existing NAP (2004–2010) has the following salient features:

1. Water-centred, poverty-linked;
2. Critical watersheds are the priority areas;
3. Multi-institutional in implementation;
4. Recognition of synergy with climate change and biodiversity conventions;
5. Supportive of multisectoral and community stakeholders' consensus in decision-making;
6. Integrates local knowledge with science-based mitigation programmes.

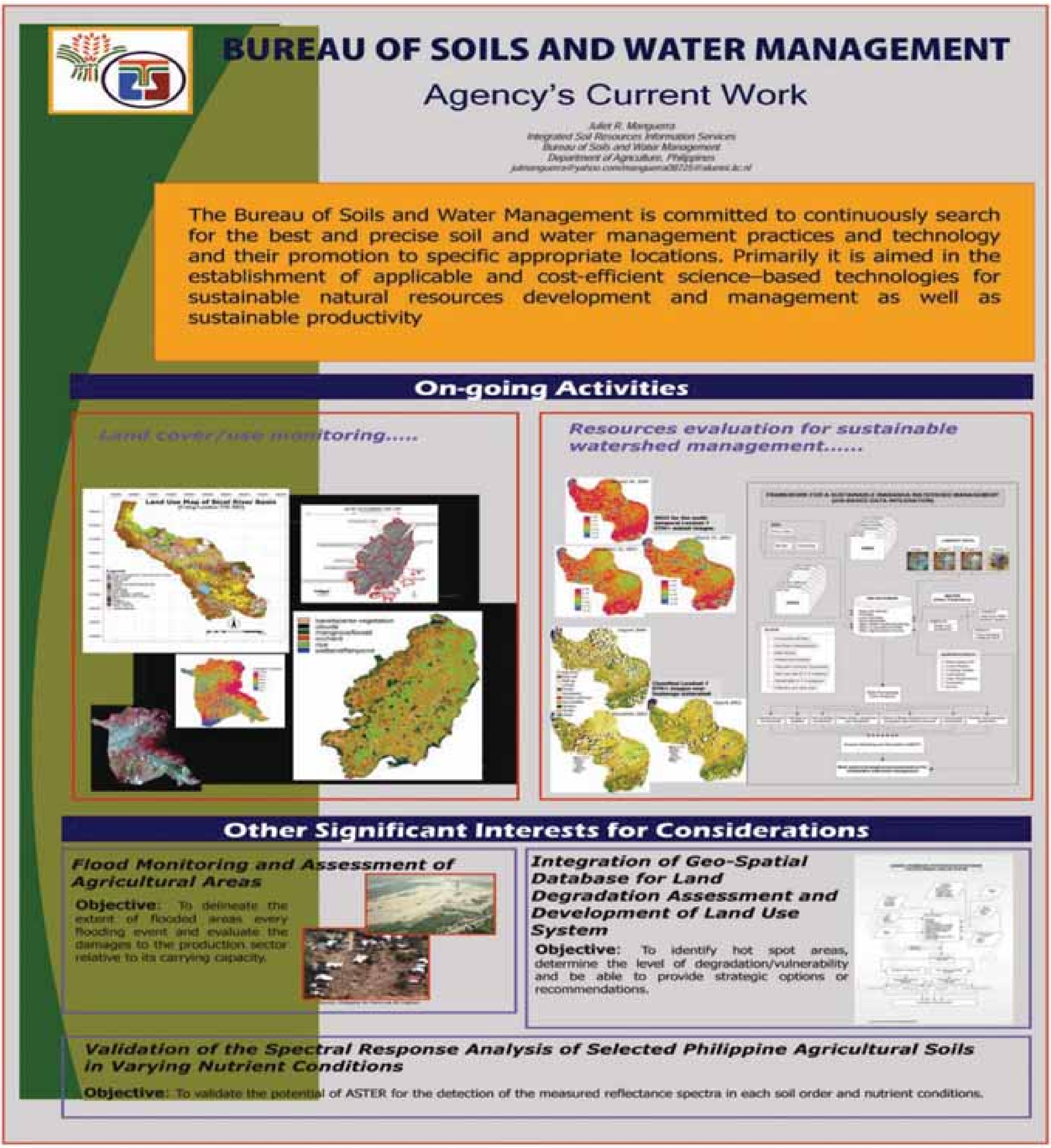

Figure 4. Poster paper on BSWM's current activities

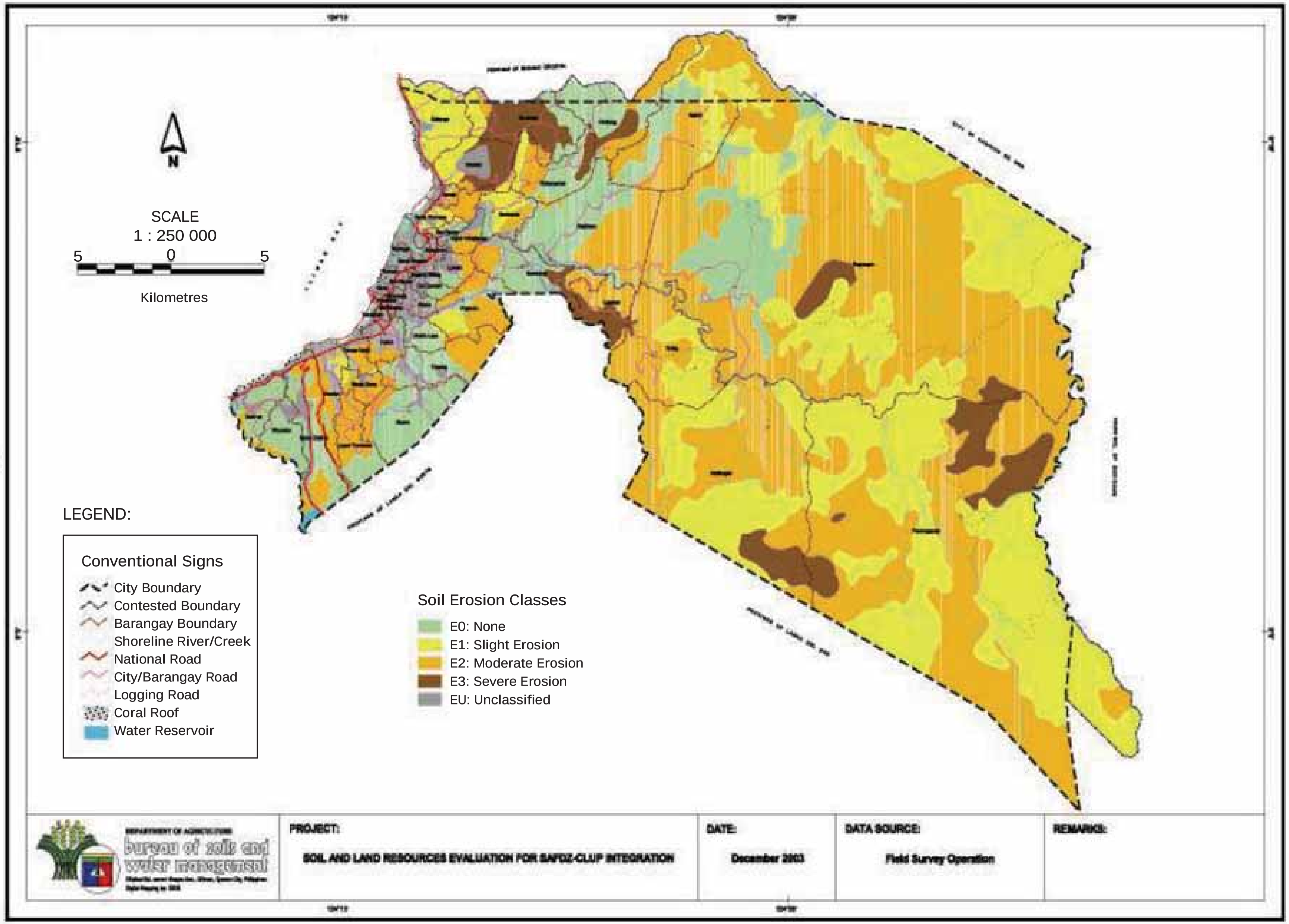

Figure 5. Soil erosion map of Iligan City

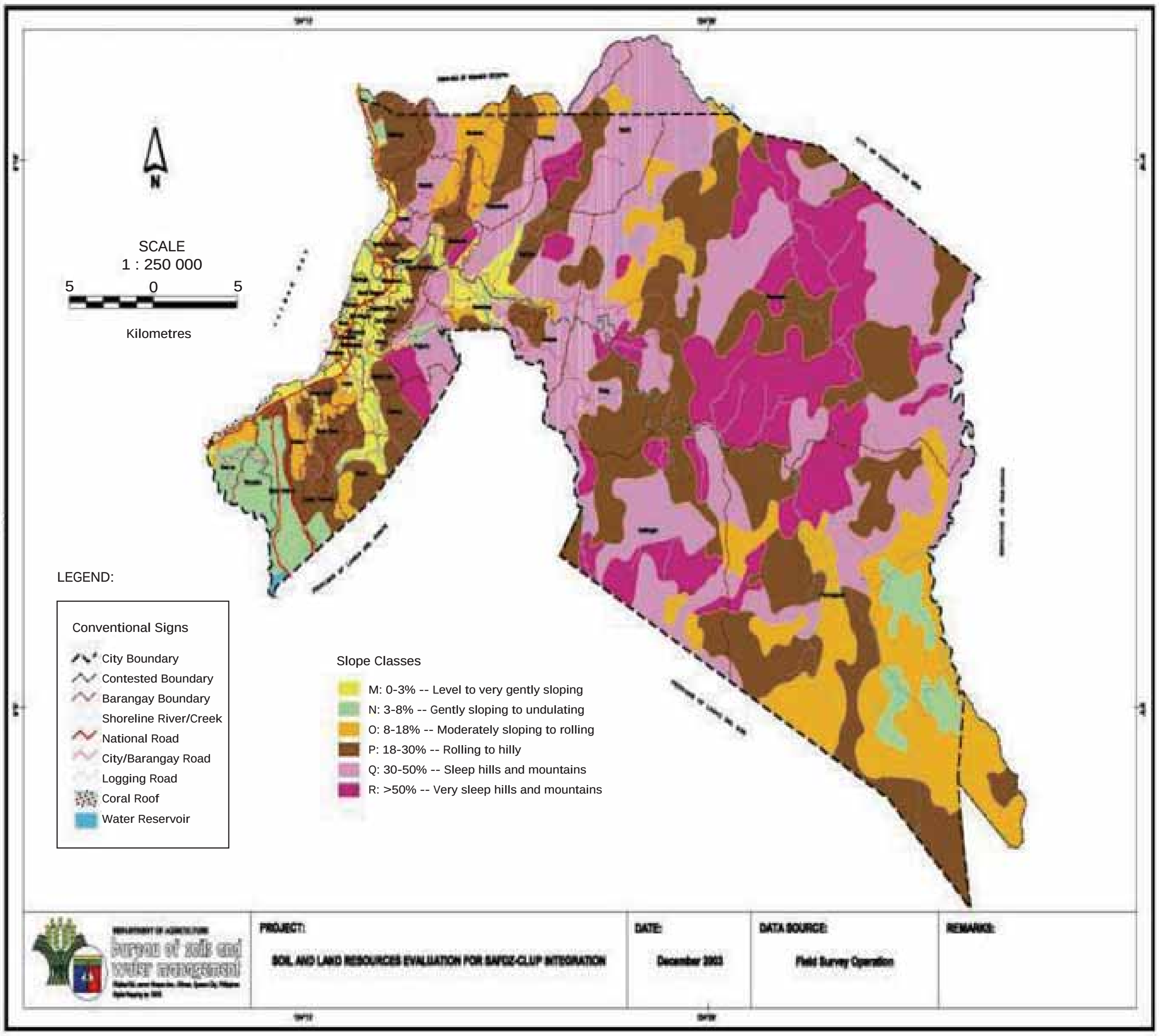

Figure 6. Slope map of Iligan City

The Philippine NAP has five programme components:

1. Land and Water Technology Development;
2. Local Governance and Community Initiatives;
3. Database Development and Harmonization;
4. Information, Education, and Communication;
5. Enabling Policy Development.

The current challenge we face is to:

1. Mobilize the Filipino scientific community for an integrated programme for methods, standards, data collection and research networks for assessment and monitoring of land degradation. This could possibly include some socio-economic instruments in the assessment of land degradation;
2. Incorporate current land-use models for land degradation predictions;
3. Develop a land degradation information system as a subcomponent of the Agricultural Land Resources Information System.

Summary and conclusion

Land degradation assessment at the national level represents several decades of fieldwork nationwide and current updating and validation efforts are done through project-based mapping activities at provincial, municipal and watershed levels. Data warehousing is done through LARIS with its three subsystems — SIS, ARIS and Water Resources Information System. There are efforts to use satellite imageries considering the upgrade of BSWM's GIS and remote sensing facilities and continuing staff development programme. However, the high cost of satellite imagery restricts areas that can be updated. Land degradation assessment is done through map overlays of land degradation factors and indicators using ArcGIS® 9.3.

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Land degradation in drylands of Viet Nam

1. Introduction

Vietnamese land resource are classified into 14 groups and 31 soil units. Soil degradation has largely been increasing both in speed and severity. Degraded land accounts for nearly 50 percent of the total land area of the country, of which 9.3 million hectares of land are exposed to the risk of desertification, including 5.06 million hectares of unused land, 2 million hectares of seriously degraded land that is currently in use and a further 2 million hectares with high risk of being degraded. Soil fertility declines are due to land erosion, landslides, laterization, salinization and acidification. The forest resource has deteriorated substantially. In 1943, the forest coverage rate of Viet Nam was 43 percent but has seriously shrunk over the last 60 years. With tremendous effort to avoid the causes of deforestation, forest coverage now stands at 37.6 percent (in December 2006). Vast deforestation occurred during 1960 to 1970 and 1976 to 1990. Deforestation has resulted in extensive land degradation, ecosystem decline and watershed deterioration. In addition, water pollution has intensified owing to improper chemical application in agriculture, poor management of industrial waste and poor environmental treatment. Underground water resources have become depleted in both quantity and quality. The potential for water scarcity is very high in the coming decades. In the last ten years, due to dry and hot weather, severe droughts and land disturbance, landslides have been prevailing in many areas, especially along the Central Coast and in the northwest, Central Highlands and the Mekong Delta (the Long Xuyen Quadrangle). These are the four priority areas in which to implement the anti-land degradation programme from 2006 to 2010.

The Central Coast has 12 provinces, from north to south, and many locations where there is low rainfall, high temperature and strong evaporation. This area is dominated by savannah, brushland, *Dipterocarpus* forest, a dry sandy coastline and poor fertility. Therefore, it is one of the most arid areas of Viet Nam, with some natural characteristics of desertification. People find it very hard to earn a living in this area due to the poverty-inducing circumstances. Therefore environmental and socio-economic issues must be addressed.

The northwest includes four provinces where erosion, landslides and soil deterioration are serious; these problems are generated by the complicated topography, steep slopes, low forest coverage and shifting cultivation practices. Local people are poor, so they exert negative impacts on the surrounding forest while eking out a living.

The Central Highlands has five provinces that were mostly covered by natural forest in the past; there are many ethnic minorities and many people migrate from the plains to cultivate the land. They have destroyed and converted forest land into farmland with rubber, pepper, coffee and fruit tree plantations. Forest coverage has declined quickly, leading to flooding in the rainy season and drought in the dry season. So, erosion, landslides and soil deterioration are major threats.

The Long Xuyen Quadrangle in the Mekong Delta comprises two provinces where mangroves are destroyed on a daily basis by aquaculture. The soil here has been contaminated by acidity and salinity. This is the main cause for land degradation in this area.

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The concept and causes

Land degradation reduces the potential of land resources via the processes of desertification and deforestation (UNDP/GEF). It is caused by a combination of factors that change over time and vary by location. These include indirect factors such as population pressure, socio-economic issues, misdirected policy and the consequences of war and international trade as well as direct factors such as land-use patterns, farming practices and other processes, for example:

- Drought;
- Land erosion, pollution, decreasing organic matter and fertility;
- The loss of vegetation cover, biological or economic productivity and the introduction of invasive species;
- Changing living environments (urbanization or conversion to agricultural land); and
- Declining watershed quality leading to loss of fertile topsoil.

Land degradation can occur in many different ecosystems such as arid, semi-arid, humid, sub-humid, coastal and mountainous areas. Although Viet Nam does not have large deserts, waste or degraded land prevails throughout the country, especially in rural areas. In the last few decades, natural calamities have intensified in frequency; owing to the extensive use of land and water resources for agriculture and industry and the destruction of forest, land degradation and water resource depletion have accelerated and on a broader scale. The number of annual landslides is predicted to increase and total land loss may reach 10 000 hectares per year. In addition, the overexploitation of marine resources and uncontrolled aquaculture have destroyed mangrove forests and impaired soil and water quality. Soil and water along coastlines have become severely polluted. Viet Nam is facing partial desertification in the narrow arrays of sandy land along the coast (Central Coast) affecting about 419 000 hectares as well as 43 000 hectares in the Mekong Delta. This generates negative socio-economic impacts, hampers rural poverty reduction and damages the environment.

The UN Convention to Combat Desertification (UNCCD) concept of ‘combating desertification’ is quite broad. In Viet Nam, this concept means combating desertification, soil degradation and reducing the impact of drought. This encompasses all activities aimed at preventing land degradation and mitigating the impacts of drought; addressing land erosion, salinization and acidification control, forest protection and development, shifting sand attenuation and water resource management should be included in an integrated National Action Programme (NAP).

Some of the major measurements to combat land degradation in Viet Nam up to 2010

In order to combat desertification, including land degradation, on 2 September 2006, the prime minister issued Decision No. 204/QD-TTg approving the National Action Programme on Combating Desertification 2006–2010 towards 2020. The main objectives of the NAP 2006 are:

- 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.

It concentrates on the following tasks:

National level

1. Make sure that the desertification process is overviewed, including the current status and causes of desertification; set up a database on the desertification situation (drought map, desertification map, land-use planning, forest land planning, river basin planning etc.).

2. Continue to review the legal framework and the policy system related to desertification, integrate action at all levels and of all sectors to develop new or amend the current policy and mainstream the activities into other policies, strategies and programmes in one common area. Since joining the UNCCD on 23 November 1998 Viet Nam has promoted and strengthened activities on environmental protection and combating desertification. A series of legal acts related to environment and combating land degradation has been revised or newly formulated to respond to the newly appeared requirement. Of great significance are the Law on Water Resource 1999, the Land Law 2003, the Law on Forest Protection and Development 2004, the Law on Environment Protection 2005, the Comprehensive Strategy on National Growth and Poverty Reduction, the Strategy for Sustainable Development in Viet Nam and the Science and Technology Development Strategy to 2010.

3. Develop crop, livestock and agroforestry systems for each priority area appropriate to each condition/ system to ensure sustainable use of land, water and forest resources as well as to improve the living conditions of local people in affected areas; technical handbooks were produced for priority areas.

To combat desertification along the Central Coast, we developed and applied technological or traditional solutions to protect water resources; harnessed wind energy to rehabilitate the coastal ecosystem; planted protection forest to hinder sand movement, enhance soil quality and moderate poverty; and improved the fertility of bare soil for effective cultivation.

To combat desertification in the Central Highlands, we identified the causes of and tested solutions to combat erosion and landslides on bare, steep sloping lands; to increase the fertility of deteriorated river basin soil; restructure planting and cropping systems in agricultural and industrial areas and planted trial protection forest along the banks of rivers and streams.

To combat desertification in the northwest, we set up steepland cultivation models, models to combat land deterioration and other models addressing desertification and livelihood enhancement.

To combat desertification in the Mekong Delta (Long Xuyen Quadrangle), we established sustainable farming systems on coastlines and in upland areas; initiated trials for planting forest on acid-sulphate and saline soils; strengthened marine management capacity and monitored the implementation of forestry planning.

4. Each province in the four priority areas has its own action plan with funding for irrigation, forestry, resource management, environmental protection, etc. To date we have many local projects with funding from international organizations, such as the World Bank, the Global Environment Facility, the United Nations Development Programme, the United Nations Economic and Social Commission for Asia and the Pacific, the Dutch Government, the Government of Japan, Deutsche Gesellschaft für Technische Zusammenarbeit, the Japan Bank for International Cooperation, the World Conservation Union (IUCN) and the Netherlands Development Organisation.

5. Awareness raising has been conducted among local and international organizations as well as ministries to identify affected localities. The awareness raising and training should be continued and socialized; promoting media participation should be the key activity in this process. For example, in collaboration with the Swedish International Development Cooperation Agency and IUCN, the UNCCD Viet Nam Office has released a leaflet entitled *Combating desertification in Viet Nam*; we have worked with Vietnamese television to produce a documentary film on combating desertification in Viet Nam; launched communication campaigns; conducted training courses to raise public awareness, prepared short films on the present status of desertification and successful models for combating desertification and arranged national seminars and workshops to share experiences in the four priority areas during the International Year on Combating Desertification.

6. Set up and implement national projects/programmes such as:

   - Continuing the National 5 Million Ha Reforestation Programme and the Comprehensive Programme on National Growth and Poverty Reduction;
   - Setting up the Partnership Programme on Sustainable Management of Forest Land;
   - Surveying and assessing the present status of desertification and identifying causes and solutions in the four priority areas;
   - Developing capacity for the UNCCD National Office, including database development and management;
   - Raising awareness on desertification for local communities in the four priority areas;
   - Providing guidelines and extension measures for combating desertification;
   - Promoting and strengthening the market information system for agricultural products in the four priority areas;
   - Studying and identifying mechanisms for mobilization and utilization of funds allocated to support combating desertification;
   - Research on the possibility to create a Combating Desertification Fund.

International level

Viet Nam has nominated national science and technology research institutions to take part in different Asian networks concerning evaluation of the desertification process; agroforestry and combating land degradation; steep slopes and shifting sand control; drought warning capacity building and combating desertification and integrated local programmes.

Conclusion

Soil deterioration in Viet Nam is rapidly increasing both in speed and severity. This is common in many large areas, especially in mountainous areas that account for three-fourths of the total natural land where the ecological balance is disturbed more seriously than other areas.

The consequences of land degradation in Viet Nam are very serious, leading to the depletion of fauna and flora, loss of land productivity and reduction of agricultural land per capita.

Several policies and programmes/projects to combat land degradation are being implemented in Viet Nam. But combating desertification and land degradation, especially in dryland is a long and complex process. It needs close cooperation, collaboration of all relevant local stakeholders and support of international organizations and the Vietnamese Government. Challenges and difficulties are still considerable, i.e. the limited collaboration of ministries, sectors and localities, limited resources both in terms of financial and technical knowledge and low awareness among different stakeholders.

However, there are still opportunities: Commitment to global economic integration of Viet Nam, the broad international cooperation strengthening strategy of the government and lessons learned and experience gained during the *Doi Moi* (innovation) process, especially in agriculture and rural development. The government is looking forward to continued support and cooperation from international organizations to successfully implement the NAP.

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Land degradation assessment in Thailand

Abstract

Agriculture has been important for socio-economic growth in Thailand since antiquity. About 21 million hectares of land area are currently under crops, 13 million hectares are forested and the remaining 17 million hectares are developed or are other topographical or infrastructural areas. In terms of agricultural production, cropland has been used to manage rapidly increasing food demand created by population growth. Farming and other activities in these areas have led to the diverse use of land for many purposes, often resulting in degradation. Degraded land covers approximately 12.88 percent of Thailand's total land area; there are five major problem soils, i.e. acid-sulphate soils (accounting for 1.71 percent of the total land area), peat soils (0.08 percent), sandy soils (3.98 percent), shallow soils (13.52 percent) and inland saline soils (3.59 percent).

This study's assessment of degraded land is based on soil series group data. These spatial data are at a map scale of 1:50 000 except for inland saline soil assessment by mapping of salt crust cover on the soil surface in the dry season. The Land Development Department has been responsible for various studies on the occurrence and rehabilitation of degraded lands since 1963. Its outputs have been disseminated to stakeholders in degraded lands and to increase awareness among decision-makers; this should lead to more sustainable use of marginal lands, particularly to enhance agricultural production to meet rising demands.

Introduction

Thailand is well endowed with diverse natural resources. The socio-economic growth of the country is dominated by the agriculture sector in terms of gross domestic product, employment and provision of food security. It is estimated that more than two-thirds of the population still lives in rural areas and earns a living from agriculture. The total land area of the country is approximately 51.4 million hectares, comprising 38 percent farmland, 25 percent forests and the remaining 37 percent is public area (such as swampland, railroads, highways and real estate).

The climate of Thailand is classified as tropical savannah (the Central Plain, north, northeast and some parts of the eastern zone), tropical monsoon (western part of southern and eastern zones) and tropical rain forest (east side of the southern zone). The average annual temperature is about 27ºC while annual rainfall is in the range of 824 to 5 248 mm. Irrigated lands are scattered all over the country, with an area of 5 million hectares or 23.8 percent of arable land, of which 46 percent is found in the Central Plain.

In recent decades, Thailand's land resources have been extensively used to increase agricultural production to provide for the burgeoning population, which has increased from 8 million in 1911 to 65 million at present. This has resulted in constant expansion of land used for agriculture and even to marginal lands and encroachment of national forest. Moreover, many areas are usually cultivated with inappropriate methods that cause environmental degradation. This situation has led to the accelerated degradation of land resources, causing soil fertility decline and anthropogenic soil salinization. This paper discusses land degradation assessment and problem soils as the result of land degradation in Thailand.

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Location of Thailand

Thailand is located between latitude 5º40' and 20º30' north and longitude 97º70' and 105º45' east. The country is bordered to the west and north by Myanmar, to the east by Lao PDR and Cambodia and to the south by Malaysia, the Andaman Sea in the west and the Gulf of Thailand in the east (Boonsompopphan *et al.* 2005).

Physiographic regions

There are six regions that are recognizable by their characteristic landforms: the northern ranges and valleys, the Central Plain, the western mountains, the southeast coast, the Northeast Plateau or Khorat Plain and the Peninsular South (Figure 1).

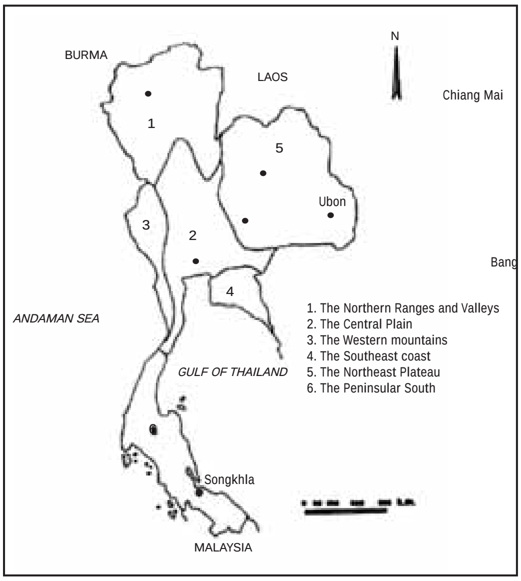

Figure 1. Physiographic regions of Thailand

1. The northern ranges and valleys: The northern ranges and valleys occupy the area above 18º north latitude. The five main parallel ranges running north–south and the valleys between them provide the catchment and headwaters of four major tributaries of the Chao Phraya River — the Ping, Wang, Yom and Nan Rivers that drain southward.

2. The Central Plain: The Central Plain extends southward from the ranges and valleys of the north to the Gulf of Thailand. It encompasses the alluvial plain of the Chao Phraya River with its many tributaries, and the surrounding piedmont belts. The plain has deep, fertile soil deposited by water from the north and also from the mountains at its western and eastern boundaries.

3. The western mountains: The western mountains represent a continuation of the Central Cordillera from the north, between Thailand and Myanmar, to the west of the Central Plain. The valleys are small; the intermontane plains are also few and small, with the exception of the Mae Sot Basin. Several tributaries of the Salween, Chao Phraya and Mae Klong Rivers originate in these mountains. The Khwae Noi and Khwae Yai collect much water from the southwest monsoon over this mountain range, and the latter joins to form the Mae Klong River.

4. The southeast coast: The southeast coast is rolling land with low hills to its north and mountains to its east, and with narrow coastal plains. It is drained by several streams and short rivers, all flowing south into the Gulf. Its coastline is much indented, exhibiting the characteristics of a sinking coast, and is fringed with rocky, forested islands.

5. The Northeast Plateau: The Northeast Plateau or Khorat Plain, is some 200 metres above mean sea level at its western edge, which is set apart from the Central Plain by the Phetchabun and Dong Phrayayen mountain ranges. These ranges extract much rainwater from the southwest monsoon and feed it back to tributaries of the Chao Phraya and Bang Pakong Rivers. The Khorat Plain, with an expanse of some 153 600 km^2, tilts to the southeast and drains into the Mekong. Its elevation does not make it a true plateau, and its plain is more saucer-shaped, with two major basins — the lower and larger Khorat Basin and the upper and smaller Sakon Nakhon Basin, divided by the Phu Phan Range. The major river system is the Mun, which drains into the Mekong.

6. The Peninsular South: The Peninsular South is a continuation of the western mountains, affording a number of basins, and river and coastal plains that are fertile and habitable. The mountain ranges form the backbone of this region, with the eastern coastline facing the Gulf of Thailand and the western coastline facing the Andaman Sea. More coastal plains and stretches of long beaches are found on the east coast, whereas the

west coast appears to be a submerged coast, with a very irregular shoreline and many estuaries. The ridges of the Phuket Range are closer to the west coast and contain more granitic cores, providing richer mineral deposits. Their location also helps them to extract greater amounts of moisture from the southwest monsoon and produces a narrow belt of very high precipitation on the west coast, in the range of 4 000 mm.

Climate

The climatic regimes of Thailand, according to Koppen's Classification, are: Savannah Climate (Aw), for the area above the Peninsular South, excluding the eastern section of the southeast coast; Tropical Rain Forest (Af), for the lower east coast of the Peninsular South; and Tropical Monsoon Climate (Am) for the rest of the Peninsular South, and also the eastern section of the southeast coast. In addition, the Humid Subtropical Climate (Cw) is applicable to the area in the far northeastern part of the north at higher elevations.

Thailand's climate has three main seasons, i.e. a rainy season from May to October, a cool and dry season from November to February and a hot and dry season from March to May.

Thailand's location creates two general effects of precipitation. First, the upper mainland section is exposed to a shorter period of the southwest monsoon, by approximately one month. The total for the north is therefore no greater than for the northeast. Second, the lower east coast of the south has an extended wet season, because the northeast monsoon that picks up moisture over the South China Sea extends well into January or February. The same northeast monsoon passing over the rest of the country does not pick up moisture and is therefore dry and cold (Boonsompopphan *et al*. 2005).

Natural vegetation and land use

Natural vegetation refers to the natural forest which, in general, defines a community of living trees and associated organisms, covering a considerable area, utilizing sunshine, air, water and earthy materials to attain maturity and to reproduce itself. The natural forest types are the evergreen forest, the deciduous forest, the coniferous forest and the beach forest.

Land use in Thailand in 2002

The total area of agricultural land in 2002 was 56.23 percent of the country; 35.75 percent was forest land and the remaining 8.01 percent consisted of swamps, idle land, urban centres, highways and other miscellaneous areas. Cultivated lands are widespread in Thailand. The lower flood plains, with prolonged, deep flooding, support direct-seeded floating rice. In vast areas of irrigated paddy fields, especially in the Central Plain, direct sowing of germinated seed is practised commonly; higher flood plains and lower terraces support transplanted rice with the help of low dykes to retain rainwater. Higher terraces, plateaus and foothills throughout Thailand support upland tilled crops, grazing and varieties of shrubs and trees for food and fibre. Cultivated crops such as rubber, coconut, oil palm and fruit trees are found in the south and southeast; cassava in the southeast and northeast; beans and cotton in the Central Plain and shifting cultivation in the mountainous areas of the north and west. Intensive cultivation of vegetable gardens and orchards (such as coconut and banana) is practised on natural levees and other high ground such as ridges, in nearly all villages and cities. It is interesting to note that orchard farming on raised beds in lowland areas with adequate irrigation is found in the Central Plain, the north and along the southeast coast.

Soil resources

Boonsompopphan *et al*. (2005) reported many kinds of soils in Thailand. They differ in thickness, texture, draining capacity, fertility, degree of flooding and in many other ways. Some are suited only for wetland rice, others for forest trees and other wide ranges of use. These properties, differing from place to place, are caused by interactions between climate, parent material, relief as well as living organisms (including human impact), over time.

The first general *Soil map of Thailand* was prepared and published in 1953, at a scale of 1:2 500 000 by R.L. Pendleton, an American soil scientist who was the agriculture and soil technology advisor to the Department of Agriculture and Fisheries. The soil units at that time were commonly called 'soil series'. These soil units were by no means as sophisticated as today's 'soil series, as defined in the *Soil survey manual* (USDA 1951). Instead, they were broad generalizations, usually on the level of the great soil group, or of the association of two or more such groups. In 1968, the second general *Soil map of Thailand* was prepared and published, at a scale of 1:1 250 000, by Moormann and Rojanasoonthon (1968). The map units were based on the soil classification outlined by Dudal and Moormann. Twenty-three basic map units were distinguished. The elements used in defining the map units were threefold: the dominant soil or association of soils; the broad group of parent material and the landform, as expressed by the general topography of the unit area.

In 1987, a draft of the generalized soil map at a scale 1:1 000 000 was made (Moncharoen *et al*. 1987). The legend of this map was based on a unified legend prepared by the Soil Management Support Services (SMSS) of the USDA under the leadership of Dr Hari Eswaran. The SMSS legend was developed so that all national maps would have a similar legend, which would permit a comparison of soils between countries. There have been a number of changes in *Soil taxonomy* since 1987; a revision of the generalized soil map of Thailand was made in 1994 by Vijarnsorn, Eswaran and Vearasilp. Finally, a new draft of the generalized soil map at a scale of 1:1 000 000 was revised again in 1999. The legend of this map basically included the soil map unit being classified at the great group level in accordance with the *Soil taxonomy* published in 1999.

From 1989 to 1992 the soil data of each province were revised; the map unit as a soil series group. Similar soil series were grouped to one unit or soil series group. These soil data are based on the scale 1:50 000 and are in digital format.

Land degradation in Thailand

There are some studies on land degradation in Thailand and a first attempt to collate the information was made by Potisuwan (1994) and later with more detailed assessment (Limtong and Potisuwan 1995). Employing the FAO–UNESCO *Soil map of the world* and more recent maps and publications produced in Thailand, Limtong and Potisuwan (1995) made evaluations of human-induced soil degradation. Some aspects of the assessment, such as the extent and rate of salinization, are very reliable due to long-term monitoring by the Land Development Department. Others, such as chemical deterioration and compaction, are subjective and based on perception of processes. However, the assessment provides an indication of the magnitude of the problem and location of areas at high risk (Moncharoen *et al*. 1999). Land degradation results in problem soils for agriculture.

Land degradation assessment

In this paper we assess land degradation from the soil series group map, scale 1:50 000. From the properties of each map unit, problem soils for agriculture could be identified, such as peat soils, acid-sulphate soils, sandy soils and shallow soils. Inland saline soils were assessed by remote sensing and GIS techniques with ground checking. The salt crust cover on the soil surface in the dry season is a criterion for mapping.

The method for mapping salt crusts is:

1. Grouping lowland soils, separate from upland soils;
2. Image analysis by Supervise Classification, TM band 1, 4, 7;
3. Make a draft map to do a field check;
4. Correct the draft map to fit field conditions;
5. Input corrected map data; and
6. Layout map.

Degraded land covers approximately 22.88 percent (11.7 million hectares) of the total land area in Thailand; there are five major soil problems (Office of Soil Survey and Land Use Planning 2006):

- Acid-sulphate soils, 1.71 percent (0.88 million hectares);
- Peat soils, with high organic matter, 0.08 percent (0.04 million hectares);
- Sandy soils, with low water holding capacity, 3.98 percent (2.04 million hectares);
- Shallow soils, 13.52 percent (6.93 million hectares); and
- Inland saline soils, 3.59 percent (1.84 million hectares).

Problem soils in Thailand

Acid-sulphate soils: Acid-sulphate soils occur in parts of the coastal lowlands (Figure 2) and in the Chao Phraya Delta they occupy an area of 600 000 hectares. Most have a very dark clayey surface, with a thickness of 15 to 30 cm. Subsoils consist of light brownish grey clay with weak prismatic or massive structure. Mottles, brownish and reddish colour, are common. In addition, jarosite mottles or straw yellow mottles are common in the subsoils. The underlying material, the so-called 'C horizon' is generally dark, is highly organic, dark brown or dark olive brown and rather clayey (Boonsompopphan *et al*. 2005).

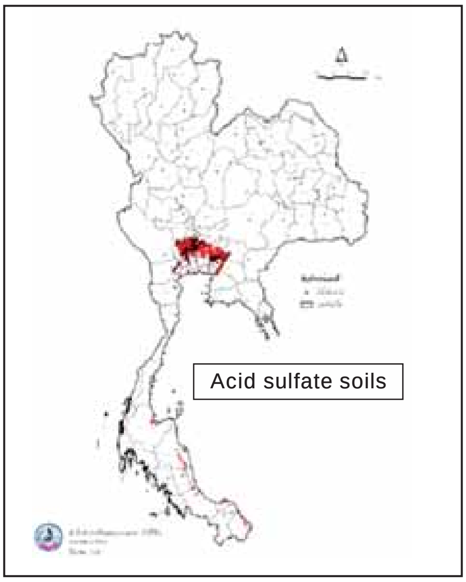

Figure 2. Acid-sulphate areas in Thailand

In general, they are poorly drained and subject to flooding during periods of heavy rainfall. Since they have a clayey texture, high water holding capacity and low permeability, soil physical conditions are favourable for rice production. However, due to some adverse chemical conditions, these soils become less productive. The chemical conditions affecting crop growth include extreme acidity, aluminium toxicity, iron toxicity, hydrogen sulphide toxicity, low base status and inadequate supply of N and P. Therefore, to use these lands for rice production the following amelioration measures are practised in Thailand:

- Leaching and drainage control in order to remove acidity and prevent oxidation of pyritic material at the same time;
- Liming. Marl and lime dust at the rate of 13–25 tonnes/hectare have been used extensively in Thailand to increase soil pH. Several research studies have revealed that the combination of leaching and liming had the greatest effect; and
- Use of N and P. Acid-sulphate soils are well known for their severe deficiency of N and P. Application of rock phosphate and ammonium sulphate at the rate of 1 250 kg/hectare and 150 kg/hectare, respectively, increased the grain yield of rice grown on extremely acid-sulphate soils.

Peat soils: The peat soils consist of organic soils in the coastal swamps. The organic soil material is less decomposed and is more than 100 cm thick. The underlying substratum includes pyritic mud clay. They are very low in fertility, with acute nutrient deficiency, and are extremely acid. Some areas still remain under freshwater swamps. Many parts have been opened for agriculture, but in most areas, production is not economically viable (Vijarnsorn and Eswaran 2002).

Sandy soils: Sandy soils include well-drained or moderately well-drained, deep, coarse-textured soils that developed from alluvial deposits on wash materials on undulating terrain. The soil has a thick sandy horizon that extends to 1 metre below the soil surface. This sandy layer is commonly underlain by medium-textured soil that has lower permeability, causing impeded drainage in the surface and sometimes waterlogging and soil erosion. These soils have low fertility and the soil reaction is strongly to medium acid. Most land uses include upland crops like cassava, sugar cane, jute and mango trees.

In some areas there are very deep sandy soils, somewhat excessively drained, occurring on alluvial terraces and fans and wash surfaces. The parent material is closely related to coarse-grained clastic rocks and coarse-grained igneous rocks in areas with less rainfall. The soil fertility is very low. Most areas are cultivated with upland crops but to a limited extent due to low productivity (Vijarnsorn and Eswaran 2002) (Figure 3).

Shallow soils: Shallow soils consist of well-drained, shallow soil with lateritic layers occurring at depths less than 50 cm below the surface. They occur on erosional surfaces underlain by layers of fine-grained clastic rocks. Land uses are normally for dryland crops, for instance, cassava, sugar cane and mango trees. However, most yields are not viable economically (Figure 4).

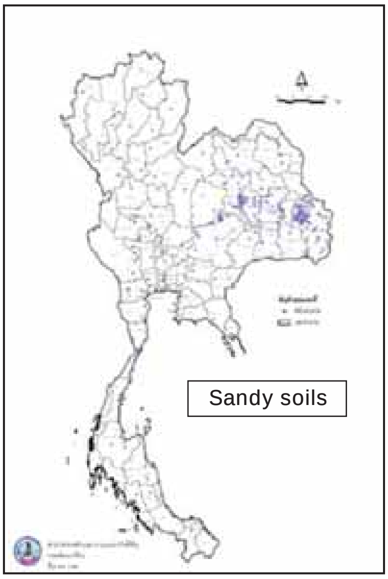

Figure 3. Sandy soil areas in Thailand

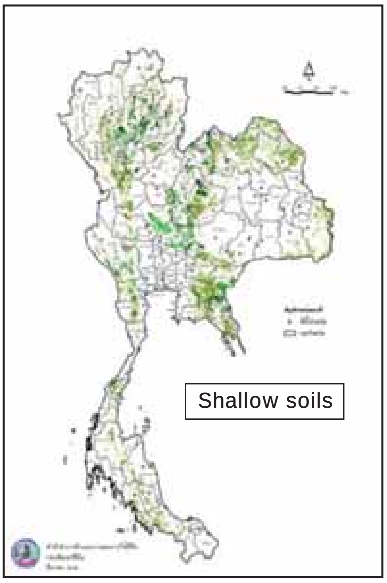

Figure 4. Shallow soil areas in Thailand

Inland saline soils: Saline soils or salt-affected soils are soils that contain sufficient salt to impair the growth of crop plants. In fact, salt injury depends on species, variety, growth stage and environmental factors. It is difficult to define salt-affected soils precisely. For simplicity's sake, however, salt-affected soils here refer to the soils that have enough salt in the root zone to give an electrical conductivity in the saturation extract (ECe) of more than 4 dS/cm at 25ºC. Apart from the salt-affected soils or saline soils along the coastal zone, referred to as mangrove soils, salt-affected soils in this section refer to inland soils where the salt source is at the surface or as underground saline water. Salts contaminating these soils are commonly introduced by capillary action, surface runoff or interflow accumulated in the soil profile. Most of the inland salt-affected soils of Thailand (Figure 5) have a sandy loam or loamy sand, leached surface horizon overlying a very hard and impermeable Bt horizon (natric horizon). The subsoils are sandy clay loam or clay loam and are generally characterized by columnar or prismatic structure.

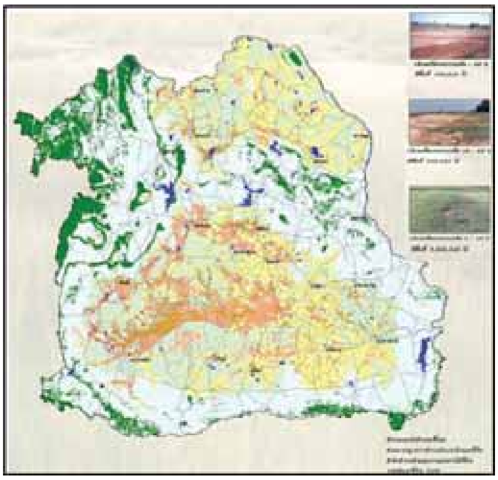

Figure 5. Inland saline soil areas (Northeast Thailand)

Due to flat topography coupled with impervious layers, the soils show dominant signs of wetness. A grey colour matrix with brownish or yellowish mottles is present throughout the soil profile. Salt and lime concretions, if present, are found in the subsoil. However, in the dry season, salt crusts are observable on the soil surface. In the profile, the dominant salt contains sodium and its amount commonly increases with increasing depth.

The management of these soils is very problematic. Furthermore, the measures strictly depend upon the degree of salinization and the particular salt-forming processes. As for general countermeasures, management of these soils involves leaching, proper drainage control, land leveling, surface mulching, organic amendments, deep ploughing and the use of salt-tolerant varieties. However, a number of management problems often occur. These are:

- The source of freshwater for leaching is normally scarce;
- Installation of a drainage system is always expensive;
- The high evaporation rate during the dry season; more irrigation water is required to exceed the evaporation rate and ensure leaching; and
- Drainage will cause substantial changes in the hydrological phenomena of the adjacent areas as well as the drained area. The change will affect the agricultural pattern of the overall area. (Boonsompopphan *et al*. 2005).

Conclusion

The assessment of land degradation in this study is based on soil series group data; these spatial data are at the map scale 1:50 000 except for inland saline soils that are assessed by mapping of salt crust cover on the soil surface in the dry season. Acid-sulphate soils, account for 1.71 percent of the total land area, peat soils 0.08 percent, sandy soils 3.98 percent, shallow soils 13.52 percent and inland saline soils caused by rock salt (mainly in Northeast Thailand) 3.59 percent.

The Land Development Department has been responsible for various studies on the occurrence and improvement of degraded lands since 1963. The outputs of its research have been disseminated to stakeholders in degraded lands to increase awareness among decision-makers to afford a better chance for sustainable use of marginal lands, particularly to enhance agricultural production to meet rapidly increasing demand.

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