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Land Resource Constraints for Sustainable Agriculture in Thailand

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ABSTRACT

The recent economic crises in Thailand have placed additional strains on the management of land for sustainable production. The resource poor farmers are decreasing the off-farm inputs from levels that were already low, and consequently receiving a lower price for their produce. Therefore, the ability of economically disadvantaged farmers to invest in conservation measures and adopt some tenets of sustainability is significantly reduced. The prognosis for the near future is enhanced land degradation, which entangles the farmers in the poverty spiral. To develop appropriate policies to address this issue, the Department of Land Development is considering several options, a starting point of which is a reassessment of the land resource constraints. The soil map of Thailand at a scale of 1:1 million was used for the national evaluation and more detailed maps for other site-specific constraints. The national soil map was combined with climatic and land-use data to evaluate important land-related constraints for agriculture. The study showed that there was about 6.6% of the total land area that is relatively free of major constraints and that this land would remain highly productive for many more generations. A further 26% of the total land area had some major constraints, which would require better than low-input agriculture to maintain sustainable production. This is the land that should be given priority in resource management programs. The remaining land area was considered as fragile and it is recommended that most of this should be kept out of agricultural production.

INTRODUCTION

In the past when supply and demand sides of the food security equation were met, land was considered bountiful though with limitations for food and fiber production. Traditional societies practiced a rationale that increased the exploitation of land to the extent that it became barren. Shifting cultivation was a response to this notion of land capability limits. Cultivators moved progressively to new areas to maintain their level of production and to enable the previous piece of land to recover. With progressive socio-economic development, there were new demands on not only the land, but also the desire to maintain the changing quality of life. In the last few decades, the ever-increasing demand for land, the recognition for a balance in the allocation of land for its different uses, and the increasing emphasis place on the quality of the environment have collectively resulted in a distinctly different value of land. Land is increasingly viewed as a scarce commodity, which has to be protected and preserved. Though historically land was viewed as a status symbol, it is today being viewed as an investment opportunity and an indicator of wealth. Enhancing land quality is emerging as a national issue particularly in countries where agriculture contributes a major component to the gross domestic product.

In the last decade, desertification has been emphasized as a land degradation process that reduces the quality of the land and one about which all countries must be vigilant. Thailand, like many other third world countries, has never made a national assessment of land degradation nor has a program of monitoring land degradation. In fact, as no methods exist to assess and monitor land degradation (Beinroth et al. 1994), this was not part of the national program of resource inventory. In addition, as agricultural production has been increasing in the past few decades and Thailand exports many crops or crop products decline in productivity was not envisaged. However, the declines in other countries, the falling revenues from agriculture products, and the environmental problems that are arising, has created new challenges to evaluate the situation and implement remedial programs (Eswaran et al. 1993). The present national analysis is a first step in the larger program of evaluating desertification and it impacts.

Land degradation

There are many studies on land degradation in Thailand and a first attempt to collate the information was by Potisuwan (1994) and later a 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, is very reliable due to long term monitoring by the Department of Land Development. Others, such as chemical deterioration and compaction, are subjective and based on perceptions of processes. However, the assessment provides an indication of the magnitude of the problem and location of areas at high risk.

There are human-induced processes that permanently alter the quality of the land. Urbanization is such a process, whereby the building of houses and infrastructure such as roads and railways not only seals the land surface but also changes the ecology of the land unit. Reservoirs have totally altered the hydrology of watersheds with impacts ranging from altering the intensity of degradation processes to

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irreversibly changing habitats. Sealed highways have similar local effects. There are also management technologies, which have negative or beneficial effects on degradation. Bunding for paddy rice production reduces erosion but promotes redoximorphic conditions in the soil. The sequential oxidation and reduction condition that is induced promotes ferrolysis, a degradation process. Under induced wetland conditions, biological processes are enhanced. The puddling of soil results in destruction of soil structure that is beneficial for rice cultivation but which presents problems for subsequent dryland crops. Contour terracing reduces erosion on sloping land but also reduces the supply of silt and nutrients to alluvial flats. Some processes are periodic. Slash and burn agriculture with long fallow periods allows steady-state conditions permit to develop which, the land to rejuvenate. However, reduced fallow periods become destructive, as the land is not permitted to recover (Eswaran, 1994). Such processes are site-specific and require on-site inspection for assessment. They are not considered here.

The inherent quality of the land is a major factor that determines the rate and degree of land degradation. For agricultural uses, the quality is related to the major land resource stresses. Identifying the stresses is a first step in assessing land quality and the eventual task of monitoring degradation.

Table 1. Major land resource stresses or conditions.

Stress Class	Land Quality Class	Major Land Stress Factor	Criteria For Assigning Stress
25	IX	Extended periods of moisture stress	Aridic SMR, rocky land, dunes
24	VIII	Extended periods of low temperatures	Gelisols
23	VIII	Steep lands	Slopes greater than 32%
22	VII	Shallow soils	Lithic subgroups, root restricting layers < 25 cm
21	VII	Salinity/alkalinity	"Salic, halic, natric" categories
20	VII	High organic matter	Histosols
19	VI	Low water holding capacity	Sandy, gravelly, and skeletal families
18	VI	Low moisture and nutrient status	Spodosols, ferritic, sesquic & oxidic families, aridic subgroups
17	VI	Acid sulfate conditions	"Sulf" great groups and subgroups
16	VI	High P, N, organic compounds retention	Anionic subgroups, acric great groups, oxidic, families
15	VI	Low nutrient holding capacity	Loamy families of Ultisols, Oxisols.
14	V	Excessive nutrient leaching	Soils with udic, perudic SMR, but lacking mollic, umbric, or argillic
13	V	Calcareous, gypseous conditions	With calcic, petrocalcic, gypsic, petrogypsic horizons; carbonatic and gypsic families; exclude Mollisols and Alfisols
12	V	High aluminum	pH <4.5 within 25 cm and Al saturation > 60%
11	V	Seasonal moisture stress	Ustic or Xeric suborders but lacking mollic or umbric epipedon, argillic or kandic horizon; exclude Vertisols
10	IV	Impeded drainage	Aquic suborders, 'gloss' great groups
9	IV	High anion exchange capacity	Andisols
8	IV	Low structural stability and/or crusting	Loamy soils and Entisols except Fluvents
7	III	Short growing season due to low temperatures	Cryic or frigid STR
6	III	Minor root restricting layers	Soils with plinthite, fragipan, duripan, densipan, petroferric contact, placic, < 100 cm
5	III	Seasonally excess water	Recent terraces, aquic subgroups
4	II	High temperatures	Isohyperthermic and isomegathermic STR excluding Mollisols and Alfisols
3	II	Low organic matter	With ochric epipedon
2	II	High shrink/swell potential	Vertisols, vertic subgroups
1	I	Few constraints	Other soils

SMR = soil moisture regime
STR = soil temperature regime

Table 2. Matrix defining land quality classes.

Soil Performance	Soil Resilience		
	Low	Medium	High
Low	IX	VIII	VI
Medium	VII	V	III
High	IV	II	I

METHOD

There are many stresses that a land resource system and specifically soils experience (Buol and Eswaran, 1994). However, there are frequently one or two major stresses that prevent the use of the land for most agricultural purposes. Some of these stresses cannot be corrected, e.g. low temperatures, unless heated glass-houses are used. Others may be corrected, e.g., irrigation for areas with water stress. Correcting the major stress may or may not ensure sustainable use of the soil. Other stresses may be present or correcting one stress may result in creating another stress. An example is irrigation in dry lands without adequate drainage. The result is rapid salinization, which reduces the quality of the land.

The 1:1,000,000 soil map of Thailand is the basis for the current land degradation assessment. USDA soil taxonomy (Soil Survey Staff, 1999) terms are used in the legend of the map. The classification terms provide information on constraints and potentials of the soil (Eswaran, 1978). Each polygon is evaluated for the factors, with the factors considered, through means of a priority listing. Once a factor is decided, a relative intensity is assigned based on the soil attributes. Multiple factors are not considered due to limitation of the scale of assessment and paucity of data. Previous investigations in Thailand and behavior of similar soils in other parts of the world are used as a basis for making judgments. The pedon database of Thailand has information for about 1,000 pedons. Climate and land use maps are also available for consultation. Trends in rural population density were also used as a guide to making judgments. Finally, the method of conservation technology implemented in different parts of the country was used as an indicator of potential degradation.

Based on the 1:1,000,000 soil map of Thailand, which also includes information on soil climate, a broad assessment of the major land resource stresses was made using the procedure of Eswaran et al. (1999). In the map, each soil is

Table 3. Properties of the inherent land quality classes (Obtained by a combination of the performance and resilience attributes of soils in the context of their inherent stresses).

Land Quality Class	Properties
I	This is prime land. Soils are highly productive, with few management-related constraints. Soil temperature and moisture conditions are ideal for annual crops. Soil management consists largely of sensible conservation practices to minimize erosion, appropriate fertilization, and use of the best available plant materials. Risk to sustainable grain crop production is generally <20%.
II & III	The soils are good and have few problems for sustainable production. However and particularly for Class II soils, care must be taken to reduce degradation. The lower resilience characteristics of Class II soils make them more risky, particular for low-input grain crop production. However, their productivity is generally very high and consequently, response to management is high. Conservation tillage is essential, buffer strips are generally required and fertilizer use must be carefully managed. Due to the relatively good terrain conditions, the land is suitable for national parks and biodiversity zones. Risk to sustainable grain crop production is generally 20-40% but risks can be reduced with good conservation practices.
IV, V, & VI	If there is a choice, these soils must not be used for grain crop production, particularly soils belonging to Class IV. All three Classes require important inputs of conservation management. In fact, no grain crop production must be contemplated in the absence of a good conservation plan. Lack of plant nutrients is a major constraint and so a good fertilizer use plan must be adopted. Soil degradation must be continuously monitored. Productivity is not high and so low input farmers must receive considerable support to manage these soils or be discouraged from using them. Land can be set aside for national parks or as biodiversity zones. In the semi-arid areas, they can be managed for range. Risk to sustainable grain crop production is 40-60%.
VII	These soils may only be used for grain crop production if there is a real pressure on land. They are definitely not suitable for low-input grain crop production; their low resilience makes them easily prone to degradation. They should be retained under natural forests or range and some localized areas can be used for recreational purposes. As in Class V & VI, biodiversity management is crucial in these areas. Risk to sustainable grain crop production is 60-80%.
VIII & IX	These are soils belonging to very fragile ecosystems or are very uneconomical to use for grain crop production. They should be retained under their natural state. Some areas may be used for recreational purposes but under very controlled conditions. In Class VIII, which is largely confined to the Tundra and Boreal areas, timber harvesting must be done very carefully with considerable attention to ecosystem damage. Class IX is mainly the deserts where biomass production is very low. Risk to sustainable grain crop production is >80%.

assigned one major stress, if stresses occur. To do this, the stresses were listed in a priority ordering (Table 1) and each soil unit (polygon on the map) was tested to determine if it meets any of the 24 (from number 2 to 25, in Table 1) identified stresses. If they failed to meet any of the 24 stress classes, then the polygon was indicated as having "Few Constraints" and classified as class 1. It is for clarity of the map that multiple stresses are not depicted, though it is recognized that these may be the rule rather than the exception. Locally important stresses can be represented on national or regional maps.

Each of the 24 stresses listed in Table 1 requires a different level of financial investment to correct for agriculture use. The ability to correct the stress with minimal cost was the over-riding factor employed to prioritize the classes in the list. The cost of correcting the stress varied with the locality and the kind of stress. For sustainable development, an understanding of the kinds of stresses and the costs involved for correction and maintenance is essential. In this study, the quality of the land was also assessed (Table 1). Description of the major land resource stresses or conditions, and soil and climate information was used to empirically assign land quality classes (Table 2).

RESULTS AND DISCUSSION

The results of the GIS analysis are presented in Figures 1 and 2 and in Table 4. Figure 1 shows the distribution of lands with different constraints for agricultural use. The eastern and northern part of the country is bordered by low hills and these steep lands occupy about 30% of the land (Table 4). Plains or undulating land (Fig. 2) occupies much of the interior of the country. The central plains, which are the lowlands, are occupied by wet soils where most of the rice is grown. They have a number of constraints, the most important of which is extreme acidity in the areas where acid sulfate soils predominate (Fig. 1). The remaining uplands experience moisture stress for at least four months a year. Many of these soils are also sandy and have a low water holding capacity. These lands occupy about 30% of the country.

Rice is a major export crop in Thailand and constraints to rice production arise from many factors. In the areas outside the Central Plains, a deficiency of water is a most serious soil-related constraint to rice production. In the Central Plains, flooding with consequent crop submergence is a problem not easily corrected through engineering works. Many rice-growing soils also suffer from nutrient deficiencies. Nitrogen deficiencies are extremely common followed by problems with phosphorous availability. Locally, other nutrients such as sulfur, zinc, and copper may also present problems. Finally, the process of rice cultivation – puddling of the land – also creates problems for the post-rice or off-season crops. The latter problems are so overwhelming that the low-input farmers generally fallow the land. In this analysis, it is not possible to evaluate each of these constraints due to the scale of assessment. However, many of these constraints such as nutrient and soil structural problems, are incorporated in the generic constraints listed in Tables 1 and 4.

The GIS analysis (Figure 2 and Table 4) showed that about 30% of the land area is comprised of steep land and this area was assigned to Inherent Land Quality Class (ILQC) VIII. Most of this land is under some form of forests and much of it has been logged at least once in the last century. Though they are not amenable to low-input agriculture, these ecosystems are under onslaught from increasing slash and burn agriculture. Land-less persons have few options but to move into this area. The traditional hill-dwelling tribes are also seeking more lands due to reduced fallow periods. Even land that has been set aside for parks and national reserves are not free from encroachment. Reducing the population pressure on this type of land is a challenge that is currently being lost by the Government. ILQC VII soils are shallow or saline, or have excessive acid organic matter and occupy about 4% of the land area. The shallow soils and those with salinity are distributed in the northeast plateau. Management of Class VII soils requires special technology, which the resource poor farmers cannot afford. The farmers have a great struggle to earn a living.

ILQC VI soils, which occupy 33% of the area, have a variety of constraints most of which are physiochemical. These stresses affect the productivity of the land and as these lands are flat to undulating, they are used for agriculture. They also occur in the semi-arid part of the country and so water stress is an additional limiting factor. Large areas of Class VII soils have low water-holding capacity. These soils are sandy or have a skeletal particle size. At present, the productivity of these soils is very low but one, which can be enhanced through application of sustainable land management technologies. Class V and IV lands occupies 8 and 18% respectively (table 1). These two classes of lands dominate the agricultural lands of the country. Productivity is generally low though with improved management practices, it is possible to become sustainable.

Class II and III lands have the best soils of the country and are largely used for rice production and other cash crops. Together they occupy about 6.6% of the land and account for a large part of the earnings from agriculture. These soils have fewer constraints than others do in the country but current productivity levels, due to a multitude of reasons, are low. There are opportunities to improve the productivity.

CONCLUSION

Land is a limiting resource in Thailand as in many of the third world countries. With time, the situation will worsen due to soil degradation which reduces the performance of the soil. Exponential growth of urban centers consumes large areas of prime land as the centers originally developed on lands that had potential to feed the community. Those countries which have opted to adopt large-scale irrigation programs to compliment their food producing capacity are generally at risk due to salinization and or alkalization which slowly but surely accompanies irrigation in arid and semiarid environments. In the drier countries of the world, supply of water may become a limiting factor before the inability of the land to produce is felt (Postel, 1998).

Another factor that prevents efficient use of land in Thailand is the purchasing power of the land users, which is the result of poverty. Appropriate technological inputs can double production. However, farmers have no capital to

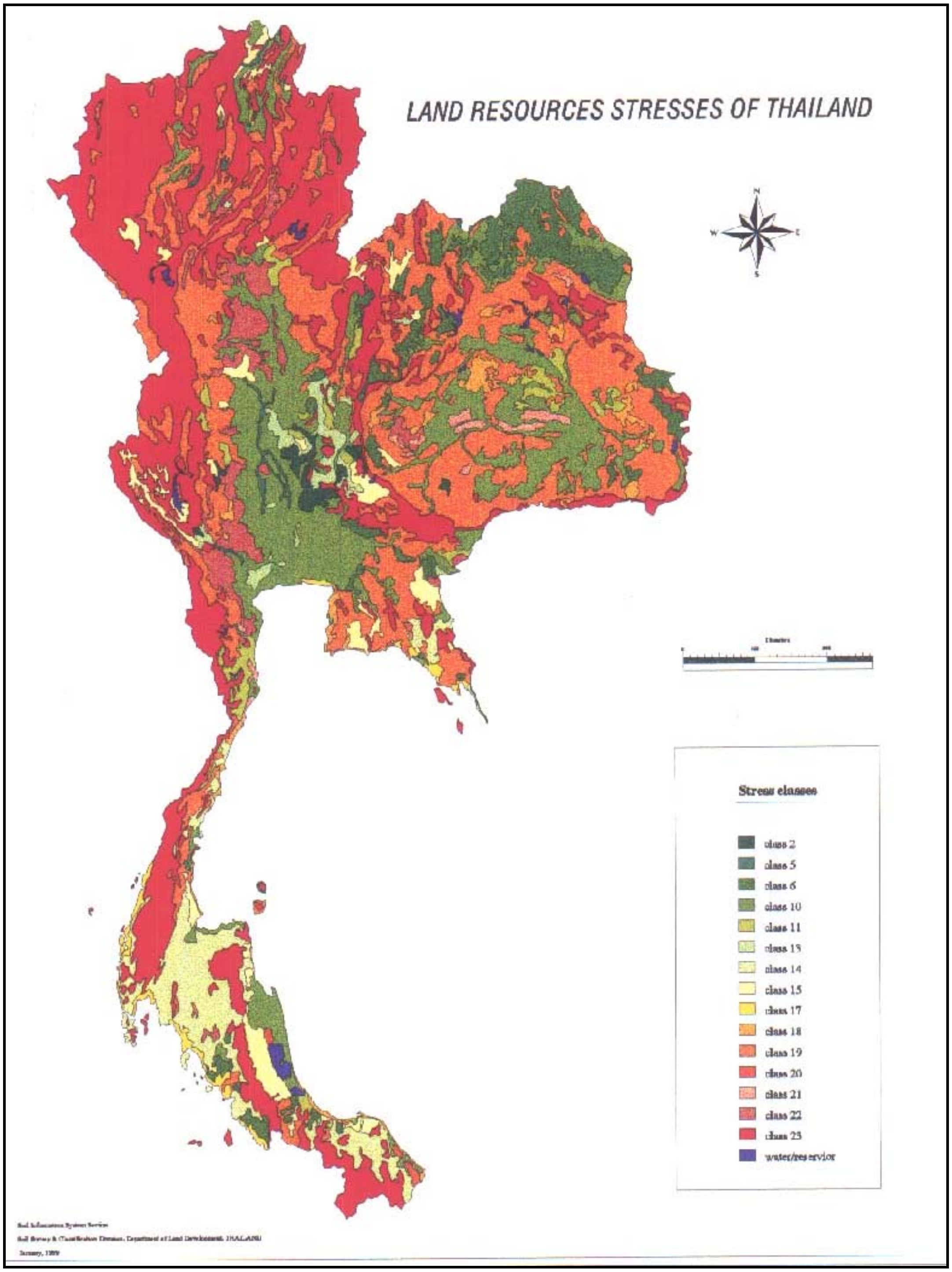

Figure 1. Land resources stresses of Thailand

Invest on the land or no incentives, when they do not own the land. Further, they have fewer facilities and an inadequate knowledge base to implement land management technologies and thus there can be few expectations of managing land degradation. Sustainability and the efficient use of the land can only result by the appropriate application of modern knowledge. Reincarnating past technologies is not a solution to the challenges of today.

The analysis of constraints in the use of land resources clearly indicates that sustainable agriculture is a major challenge that decision-makers and land users face. It is only through an understanding of the location of such constraints that mitigating technology can be effectively implemented. Finally, in the absence of a program of monitoring little progress to attain sustainability can be attained. This analysis provides new information for re-evaluation of the country's land use policy and can be used for targeting areas for new initiatives.

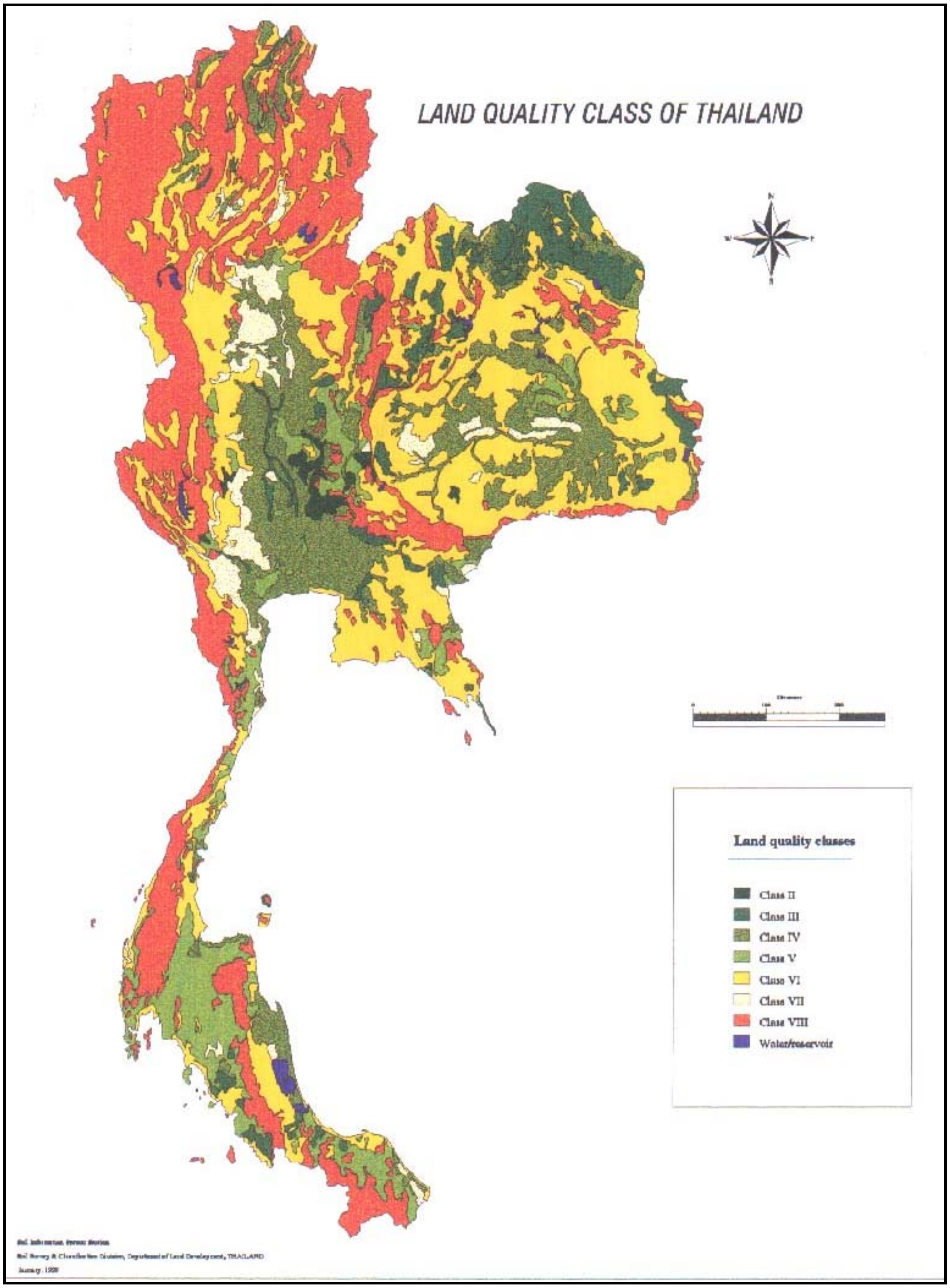

Figure 2. Land quality class of Thailand

Table 4. Land areas for major stress classes and land quality classes.

Class Code	Land Resource Stress			Inherent Land Quality Class		
	Kind	*Area (km²)*	*Percent*	Class	*Area (km²)*	*Percent*
25	Continuous moisture stress			IX		
24	Continuous low temperatures			VIII		
23	Steep lands	154,608	29.91	VIII	154,608	29.92
22	Shallow soils	17,925	3.47	VII		
21	Salinity/alkalinity	3,657	0.71	VII		
20	High organic matter	748	0.14	VII	22,330	4.32
19	Low water holding capacity	142,607	27.59	VI		
18	Low moisture & nutrient status	7,808	1.51	VI		
17	Acid sulfate conditions	4,089	0.79	VI		
16	High P, N & organic retention			VI		
15	Low nutrient holding capacity	16,915	3.27	VI	171,421	33.16
14	Excessive nutrient leaching	26,006	5.03	V		
13	Calcareous, gypseous condition	7,063	1.37	V		
12	High aluminum			V		
11	Season almoisture stress	10,340	2.00	V	43,410	8.40
10	Impeded drainage	91,057	20.61	IV		
9	High anion exchange capacity			IV		
8	Low structural stability			IV	91,057	17.61
7	Seasonal low temperatures			III		
6	Minor root restricting layer	27,836	5.38	III		
5	Seasonal excess water	2,234	0.43	III	30,070	5.82
4	High temperatures			II		
3	Low organic matter			II		
2	High shrink/swell potential	4,040	0.78	II	4,040	0.78
1	Few constraints			I		
	TOTAL	**516,933**	**100**			**100**

REFERENCES

Beinroth, F.H., H. Eswaran, P.F. Reich and E. Van den Berg. 1994. Land related stresses in agroecosystems. In:(Eds. Virmani, S.M., J.C. Katyal, H. Eswaran, I.P. Abrol) Stressed Ecosystems and Sustainable Agriculture. Oxford & IBH Publ. Co. New Delhi, India.131-148.

Eswaran, H, S.M. Virmani and L.D. Spivey. 1993. Sustainable agriculture in developing countries: Constraints, challenges, and choices. P.7-24. In: J. Ragland and R. Lal (ed.) Technologies for Sustainable Agriculture in the Tropics. ASA Spec. Publ. 56. ASA, CSSA, and SSSA, Madison, WI.

Eswaran, H. 1978. An evaluation of soil limitations from soil names. Proc. Workshop on Soil Resource Inventories. Cornell Univ. Agron. Mimeo No. 77-23. 289-314.

Eswaran, H., R.W. Arnold, F.H. Beinroth and P.F.Reich. 1999. A global assessment of land quality. In preparation.

Limtong, P. and U. Potisuwan. 1995. Country report on national soil degradation assessments. Unpublished report for the ASSOD Project of the International Soil Information and Reference Center, Wageningen, Netherlands.

Postel, S. 1994. Carrying capacity: The Earth's bottom line. In: State of the World 1994. World Watch Institute. W.W. Norton & Company, NewYork, 3-21.

Potisuwan, U. 1994. Collection and analysis of land degradation data in Thailand. Report of the expert consultation of the Asian network on problem soils. Publ. FAO, Thailand.227-249.

Soil Survey Staff. 1999. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. U.S. Dept. Agric. Handbook 436. Govt. Printing Office. 869 pp.