Assessing Biophysical and Socioeconomic Condition for Watershed Management: Case of Khlong Yai Watershed, Eastern Thailand

Rajendra P. Shrestha* and Nalina Gnanavelrajah

Abstract— *A study was carried out at Khlong Yai watershed of Thailand to assess soil erosion, and land suitability evaluation to examine the general land degradation status in terms of appropriateness of present land uses, and explore factors influencing farmers' choices on land use selection. The study used both biophysical and socioeconomic data with standard available methodologies of soil erosion assessment and land evaluation. The data were collected from several sources including household survey. The study indicates that there is however enormous changes in land uses mostly due to commercial orientation the area has no serious soil erosion problem in general. The general choice of land use in the area is for tree crops due to commodity price for higher income, and other factors, such as traditional practice and tenure arrangement, nevertheless it is worth considering appropriate management practices in the area with tree crops as such cultivation practices diminishes ecological potential of land by diminishing soil fertility and biological diversity as well.*

***Keywords*— Soil erosion, land suitability, socio-economic, Thailand.**

1. INTRODUCTION

Land resources have been adversely impacted by several factors, such as the rapid urban and industrial growth, extensive deforestation and unsustainable agriculture, including in adequate soil conservation, cultivation of steep slopes and overgrazing [1]. Inappropriate agricultural activities is one of those factors causing impacts, such as land degradation, loss of biodiversity, and even increased Carbon dioxide (CO_2) emissions. Soil erosion is one of the pervasive land degradation problems in several Asian developing countries, including Thailand. Soil erosion causes losses in soil productivity, degradation of landscape, degradation of water quality, and loss of organic carbon [5] [6]. Thailand is estimated to have its one third of land area affected by severe degradation and soil erosion due to water being the major type [2] excluding other forms of problem soils which pose serious limitation to agricultural production. Rate of soil erosion in Thailand ranges from 15 to 200 tons/ha/yr have [3]. Twelve percent of the total eroded lands of the country are primarily under field crops and shifting cultivation, which have very severe hazard severity [4].

Taking decision to put a given land unit into a specific use depends on both internal and external factors. Amongst, the biophysical factor, e.g. land quality, although is the major factor in determining land uses due to its influence on potential production, most often decisions are driven by economic and political factors [7] often leading to misuse of land or inappropriate management practices. While soil erosion assessment, and land suitability evaluation, which assesses the performance of land for specified uses, are important in the watershed context to determine the productive potential of any given land unit in the watershed, consideration of socioeconomic and political factors are equally vital for holistic planning and management of the watershed resources to achieve sustained production and ecosystem services. On this premises, this study had the following objectives:

1. Assess land degradation in terms of soil erosion severity
2. Analyze land suitability for major crops, and
3. Study the socioeconomic condition in the study area in terms of peoples' perception to examine the constraints and awareness towards conservation.

2. STUDY AREA

The study area, Khlong Yai watershed of Thailand is situated in the eastern central part of Thailand covering 170,175 ha (Figure 1). The climate is tropical monsoon with 1383mm annual rainfall and 28.3 °C annual average temperature. Three-fourth of the watershed has flat to gently undulating topography with dominant soil types of fine loamy, clayey making it suitable for cultivation. In the recent decades, the area has experienced large scale land use change and modification mostly of commercial orientation.

Agricultural land-uses cover 80% of the study area, mostly upland crops (76%) and the rest as paddy cultivation area (4%). The study site has different types of shrub mono-cropping, shrub tree intercropping, tree mono-cropping and mix-cropping implying different types of land management practices and associated soil erosion severity. Among the agricultural land-uses, pararubber, mixed orchards, pineapple and cassava are the dominant land-uses which have area coverage of

*Rajendra P. Shrestha (corresponding author) is the Coordinator of the Natural Resources Management program at the Asian Institute of Technology, Pathumthani, Thailand. Tel: +66-25245602; Fax: +6625246431; E-mail: rajendra@ait.ac.th.

Nalina Gnanavelrajah is Lecturer at the University of Jaffna, Sri Lanka. E-mail: nalina12@yahoo.com.

19.42, 16.3 12.94 and 12.14, respectively. Coconut, coconut-cassava intercropping, sugarcane, sugarcane-cassava rotation, pineapple-cassava rotation, eucalyptus and paddy were the other agricultural land-uses in the study area.

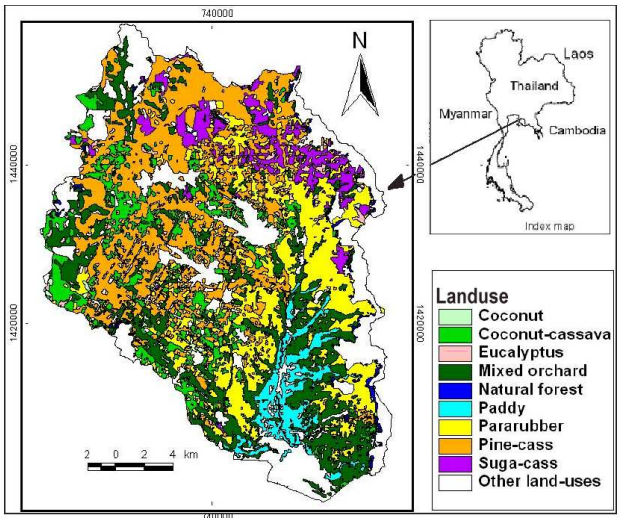

Fig.1. Location of the Study Area.

3. RESEARCH METHODOLOGY

The study aimed to asses i) the soil erosion severity in the study area, ii) land suitability, and iii) explore farmers' perception towards soil conservation. Hence, both primary and secondary data of biophysical, social and economic characteristics were collected and used in the study. Table 1 presents the secondary data used in the study were:

Table 1. Data types and sources

Data	Sources	Data type
Land-use	Department of Land Development	Land-use map 2000 Scale 1: 100 000
Soil	Department of Land Development	Soil map 2003 Scale 1:100 000
Topography	Department of Land Development	Topographic map Scale 1: 50 000
Climate	Meteorological stations in study area	Monthly Rainfall, Temperature, and evaporation 1994 - 2004

Soil erosion reduces the soil's depth and thus the capacity of land to hold water and the amount of nutrients it contains. Land-use and management practices of watershed should be aimed to keep the soil loss due to erosion below acceptable limits. In this regard the present level of soil erosion in the watershed was assessed using the Universal Soil Loss Equation (USLE) given by Wischmeir and Smith [8], which has been successfully used in several studies. The equation can be written as

E = RKLSCP

Where, E= annual soil loss (tons/ha/yr)

R = rainfall erosivity

K = soil erodibility

L = slope length

S = slope steepness

C = crop management, and

P = erosion control practice

These factors were modified in Thailand context as per available information (refer to [9] for detail methodology). R factor was computed using annual rainfall data, K from soil data, L and S combinely estimated based topography, C and P from landuse data.

Land suitability analysis when used for specified purposes, provides a rational basis for sustainable land-use and management. Each land unit has its own potentialities and limitations. On the other hand, each land-use has its own biophysical requirements. Almost all crops could be cultivated in any piece of land with external inputs. However, external inputs or improvements are expressed in terms of capital, energy, or environmental costs. The main aim of land suitability analysis is to minimize these socio-economic and environmental costs by predicting the inherent capacity of a land unit to support a specific land-use and management for a long period of time without deterioration. Biophysical suitability of the agricultural land-uses was evaluated by carrying out a land suitability classification according to Framework of land evaluation [10]. The land-use requirements were used as suggested by Land Development Department of Thailand [11] to classify four suitability classes: highly suitable (S_1), moderately suitable (S_2), marginally suitable (S_3) and non suitable (N). A total of fourteen diagnostic factors namely annual rainfall or water requirement during growing period, mean annual temperature, organic matter content, available phosphorus and potassium, soil depth, pH, cation exchange capacity, base saturation, electrical conductivity, drainage, frequency of flooding, slope gradient and stoniness were considered in this study. These factors were encoded in rainfall map and soil map.

Scores were given for each level of suitability. The weight for each diagnostic factor was assigned according to the importance of each diagnostic factor for each crop and the ease with which the factor could be managed. The factors which can not be easily managed were given more weightage compared to the factors which could be easily altered. Index overlay modeling technique was used to combine the data and perform overlay analysis [12].

$$S = \sum_i^n SiWi \quad (1)$$

where, S = Weight score for mapping unit; S_i = Score

for i^{th} diagnostic factor; W_i = Weight of i^{th} diagnostic factor

Final rating of suitability of each mapping unit was assigned as highly suitable, moderately suitable, marginally suitable and not suitable depending on the score.

Both soil erosion and land suitability assessments were carried out using vector-based Geographic Information Systems (GIS).

Field works for ground truthing and household level socioeconomic data collection were conducted. A household survey was conducted to gather information on socioeconomic status and peoples' perception toward resource degradation and conservation. Altogether 75 representative households having major land use types found in the area were interviewed by administering structured questionnaire in the early 2006.

4. RESULTS AND DISCUSSION

4.1 Soil Erosion Assessment

The computed potential soil erosion presented according to different land-use types in Table 2 indicates that 84% of the agricultural land-uses have potential erosion rate less than 2 tons/ha/yr.

Table 2. Potential erosion rate in Agricultural landuses

	Rate of erosion (tons/ha/yr)				
	2	2-4	4-12	>12	Total area
Land-use	% Area under different erosion rate				(%)
Cassava	62	13	18	7	10.46
Coconut	57	13	26	3	0.45
Coconut-cassava	60	16	22	1	0.36
Eucalyptus	70	5	17	8	1.22
Mixed orchard	87	8	4	1	15.99
Paddy	100				4.91
Para rubber	85	8	4	3	18.84
Pineapple-cassava	78	7	14	1	5.55
Pineapple	100				13.71
Sugarcane-cassava	76	4	15	5	8.67
Sugarcane					0.61
Other land-uses					19.2
Average/Total	84	6	7	3	100

Total area – 170174 ha

Six and seven percent of area have 2-4 and 4-12 tons/har/yr soil erosion, respectively. Only 3% of agricultural land-uses have potential erosion rate higher than maximum permissible limit of erosion rate (PSL) of 12 tons/ha/yr. This is due to the fact that more than three-fourth of the area has flat to gently undulating topography which is less subject to high erosion compared to the high slope areas. Figure 2 presents the distribution of areas under different rate of above PSL.

Among the land use types with relatively higher soil erosion rates were Eucalyptus, Cassava, Sugarcane-Cassava mixed crop, and Para rubber.

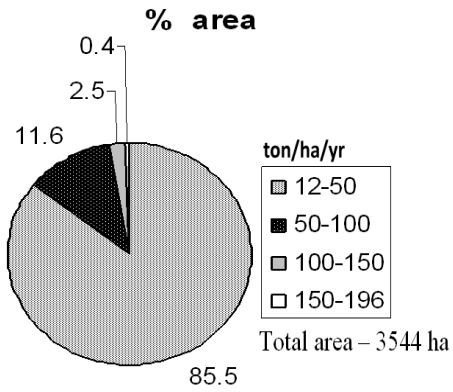

Fig. 2. Distribution of areas under different rate of erosion above permissible limit.

4.2 Land Suitability Analysis

The results of land suitability analysis of major crops of study area indicate that pineapple, cassava, coconut and orchard are the more suitable crops in terms of area of suitability according to biophysical suitability. In this regard 52.81 and 27.69% of total area is highly and moderately suitable for pineapple cultivation. The similar figures for cassava, pararubber, coconut and orchard are 45.12 and 35.38, 43.61and 37.02, 43.49 and 45.89 and 23.02 and 53.19 respectively. On the other hand sugarcane and paddy have less suitable areas compared to the above crops.

Table 3. Land suitability of present landuses.

	Area under different suitability (%)				Total area
	Highly	Moderately	Marginally	unsuitable	
Land-use	suitable	suitable	suitable		(ha)
Cassava	75	24	0	1	17858
Coconut	44	55	1	0	769
Coconut – cassava	-	100	-	-	612
Eucalyptus	100	-	-	-	2070
Mixed orchard	21	54	20	5	27205
Paddy	35	51	12	2	8351
Para rubber	45	54	0	1	32067
Pineapple-cassava	52	45	0	3	9445
Pineapple	81	16	0	3	23335
Sugarcane-cassava	9	87	4	0	14761
Sugarcane	16	76	5	8	1031
Sub total	47	46	5	2	137504
Other land-uses*					32671

* no suitability assessed

Comparison of present land use in terms of respective biophysical suitability, it was found that 47% of the present land-uses are highly suitable, 46% under moderately suitable, 5% under marginally suitable and 2% are non-suitable (Table 3). Spatial distribution of different suitable category of present land uses is shown in Figure 3. Pineapple, cassava, coconut and orchard are the relatively more suitable crops in terms of present area coverage, for example 81% and 75 % of pineapple and cassava land-uses are being cultivated in highly suitable areas, respectively. Sugarcane and paddy have relatively

less suitable areas. Only 45% or the para rubber land-uses are cultivated in highly suitable area.

4.3 Assessment of socioeconomic condition and farmers' perception

Socioeconomic Profile

The age of respondents ranged from 35 and 80 and minority (4%) percent were illiterate. 64 percent were engaged only in agriculture while 36 percent had also second occupation to agriculture. Average household size was of 4 members in the family. 49% had only owned lands, 15% had only rented-in land while 36% had both owned and rented-in lands. In general, majority farmers with tree crops, namely coconut, coconut, eucalyptus, mixed orchard, and pararubber, were observed to have owned their land. The average holding of owned land was 9.13 ha while rented-in holdings average 21.4 ha.

Number of crops grown by the farmer and cropping pattern adopted affect the household income, resilience, and sustainability of land-use. 39% respondents grow only one crop while 29, 8 and 9% grow two, three and four crops, respectively in a year. Varieties of cropping practices (monocropping, rotations, intercropping) are found for different land uses.

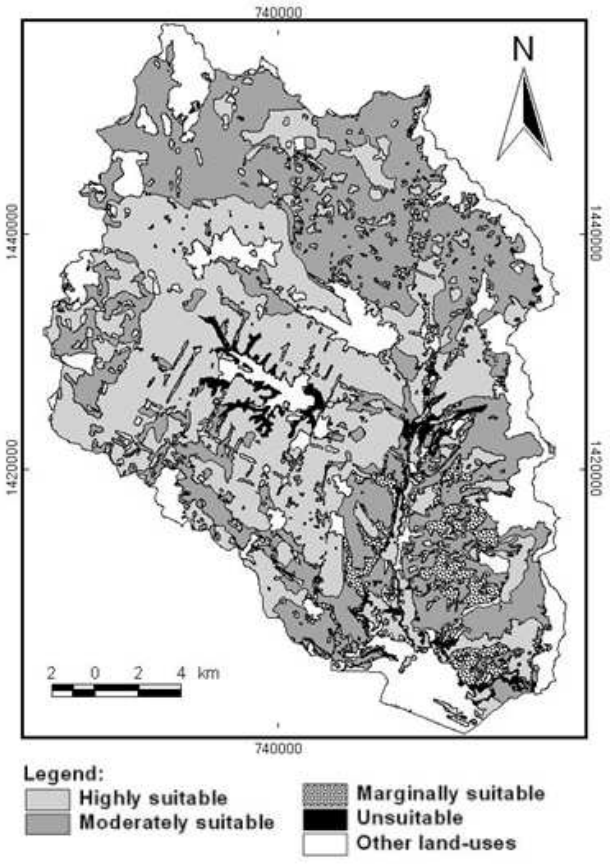

Fig.3. Suitability of present land-uses in the study area

49% of surveyed households had only owned lands, 15% had only rented in land while 36% had both owned and rented in lands. In general, most farm households growing tree corps (coconut, eucalyptus, mixed orchard, para rubber) have their own land compared to those who are growing shrub crops (sugarcane, cassava). The average size of owned land in the study area was 9.13 ha, where as 21.4 ha in case of rented in land. More than four fifth (83%) of respondents having own land had title deed, which provides full ownership of land. Percentages of respondents having other category of land documents which do not provide full ownership like title deeds do, such as *Nor Sor 3, Sor Tor Kor, Sor Por Kor*, were 1.59, 3.17 and 12.69, respectively. Among the farmers having own land, all who cultivates eucalyptus, mixed orchard, paddy, pineapple and sugarcane-cassava and 75% of land-users of coconut, coconut-cassava, para rubber, and sugarcane had title deed.

Landuse Choices and Conservation Practices

According to the survey 40% of the farmers take decision about their land-use based on commodity price while 32% are following land-uses as traditional practice (Table 4). Another 12% of land-users select land-use based on the criteria of the ease of cultivation or one time investment needed for long period of benefits. Other 4% and 1% decide on type of land-use, based on basic needs and guide from officers respectively.

Pineapple, pineapple-cassava and sugarcane-cassava growers made their land-use decisions either by commodity prize or due to traditional practice. All farmers cultivating sugarcane responded that they were growing sugarcane as a traditional practice.

Table 4. Basis of land use choices

Land-use wise respondents	Basis of decision Making (% HH)					
	Commodity price	Traditional practice	Land quality	Basic needs	Guide from Officers	Ease of Cultivation
Cassava	33	45	11			11
Coconut		75		25		
Coconut-cassava	50	25	25			
Eucalyptus	75					25
Mixed orchard	33	25	17	8	8	8
Paddy		25	50	25		
Para rubber	42		8			50
Pineapple	70	30				
Sugarcane		100				
Pineapple-cassava	60	40				
Sugarcane-cassava	57	43				
Total	40	34	9	4	1	12

Meeting the basic needs as a factor of land-use decision was reported by few farmers growing coconut, mixed orchard and paddy. Other farmers cultivating cassava (11%), eucalyptus (25%), mixed orchard (8%) and para rubber (50%) responded that they decided to cultivate such crops because of ease of cultivation or need of only one time big investment. Land quality was used as a criterion in land-use decision by few farmers growing cassava (11%), coconut-cassava (25%), mixed orchard (16%), paddy (50%) and para rubber (8%). Only 8% of mixed orchard farmers or 1% of total respondents makes land-use decisions based on guidance from officers in the study area. On an average, 80% households did not wanted to change their land-use in

near future except the households currently growing sugarcane of which majority (75%) wanted to change to orchard.

With regard to the farm households practicing soil and water conservation practices, more than half (56%) of the respondents were found adopting conservation practices. Among those adopting conservation measures a substantial majority (83%), use only organic manure while, 12% use both organic manure and mulching and 5% use organic manure and bio-fertilizers. Farmers growing eucalyptus or paddy did not practice any conservation practice. On the other hand all the farmers growing pineapple or sugarcane-cassava adopt conservation measures. Some farmers from land-uses orchard, coconut, pineapple-cassava and coconut-cassava use organic manure as the conservation measure. Organic manure and bio-fertilizer was used by sugarcane or sugarcane-cassava land-users.

Economics of Production

Economic analysis was done to compare the economic return from different land-uses. The land-uses in the study area differ in terms of time span between investment and return, as there are short term crops and different perennial crops. Hence, benefit-cost ratio was calculated based on net present value up 28 years. The time period of 28 years was selected because of the lifespan of most perennial crop land-uses in the study area last up to 30 years and land-use such as eucalyptus which has up to 7 years for one cropping would complete 4 cycles during 28 years. The results indicate that land-use sugarcane had the least benefit cost ratio of 2.08, while land-use coconut had the highest of 5.38. Next to coconut, eucalyptus has higher B/C ratio of 5.32. Mixed orchard and coconut-cassava has 3.55 and 3.49 respectively. Comparatively higher B/C ratio for coconut and eucalyptus is mainly attributed to the very low cost of production of these crops, due to less intense weed and fertilizer management. Pineapple-cassava, pineapple, sugarcane-cassava, para rubber, cassava, and paddy has B/C ratio 3.2, 3.06, 2.73, 2.5, 2.45 and 2.39 respectively (Table 5).

Table 5. Benefit cost ratio of land-uses

Land-use	Benefit-cost ratio
Cassava	2.45
Coconut	5.38
Coconut-cassava	3.49
Eucalyptus	5.32
Mixed orchard	3.55
Sugarcane	2.08
Sugarcane-cassava	2.73
Para rubber	2.5
Pineapple	3.06
Pineapple-cassava	3.2
Paddy	2.39

Perception on Environment

Perception of farm household regarding some aspect of environment, such as importance of organic matter, soil fertility status, and soil erosion, was investigated using questionnaire survey as it helps to understand their level of awareness and attitude towards environmental conservation.

Regarding importance of organic matter (OM) and its application in the agricultural field, almost all farmers (97%) are aware that organic matter improves land quality. However, majority 52% were not actually applying OM for various reasons, such as high cost, no OM production in farm household, and old age of plantations. In relation to soil fertility status, most farm households (63%) in the study area thought that the soil fertility in their agricultural field had been decreased in last ten years or so and the rest thought no change or were not about the either kind of change. Interestingly, most of them who thought the soil fertility has decreased were the household growing upland crops not paddy.

About 47% farm household thought that soil erosion in their farm land has increased in the recent past and again these were the farm households mostly growing the upland crops. This is interesting to note that computed soil erosion assessment as discussed before however did not show significant erosion with respect to permissible soil loss, farm households are concerned about the soil loss implying greater awareness about the need of soil conservation. In relation to farming practices, there were mixed responses about the mono-cropping and productivity depending upon the type of crops they have been growing although mono-cropping in general is regarded to decrease soil fertility and less stable farming system.

5. CONCLUSION AND RECOMMENDATIONS

The study generates some important information that could be used to guide watershed management activities in the area. The study revealed that the area has no serious soil erosion problem as small percentage of area exceeds permissible soil loss. Nevertheless, substantial proportion of household perceiving increased soil erosion in the recent past calls for cautions to practice improved management practices and not erode soils.

Of the evaluated landuses, the land suitability analysis of present land-uses shows that 47% of the present land-uses are highly suitable, 46% under moderately suitable, 5% under marginally suitable and 2% are non-suitable. This implies there is scope and need to appropriate match the land uses according to the land quality for enhancing the production while conserving the health of soil for sustained production. As indicated, commodity price is one of the major factors influencing land use decision-making and the tree-crops have usually higher benefit compared to the annual crops, and majority of farmers would like to have such crops but are constrained because of the land tenure arrangements. Tree-crops seem to be the first choice because of the fact that there is market available and relatively stable price. Choice of tree crops might also help claim long term ownership on the given piece land.

It is however important to give due consideration for better management practices in these lands. It is

particularly important in case of shrub crops with mono-cropping, such as cassava, pineapple and sugarcane as they tend to have relatively higher erosion and less plant diversity undermining ecological stability of land unit. Farmers are well aware of the beneficial effects of organic manures and trees on soil fertility but are not adequately able to practice because of unavailability or high cost and this calls for necessary support to enable to them to use organic matter for maintaining soil quality and eventually sustain production.

Although not within the scope of this paper to discuss, it is most often the national policy for economic gain which has been influencing the land use particularly the conversion to monocropping of economic commercial crops , such as cassava, pararubber. Land degradation and land suitability assessment to assist in making right kind of land use decision making are prerequisites from the perspective of food security, ecosystem sustenance and also the mitigation and adaptation of climate change, a global concern.

ACKNOWLEDGMENT

The authors like to acknowledge the assistance of all those individuals and organizations who kindly provided or made available the spatial data required for the study. Thanks are also due to the individuals who helped in the field data collection.

REFERENCES

[1] UNEP, (2000). *The State of the Environment, Asia and the Pacific. Global Environmental Outlook*. London. Earth scan. P. 72-97.

[2] Dent, F.J. (1992). Environmentally sensitive aspects of agricultural development. In: *Environmental Impact Assessment in Agricultural Projects in Asia and the Pacific*, Asian Productivity Organization (APO), Tokyo.

[3] Sathirathai, S. (1995). Roles of property rights on the adoption of conservation practices in Nothern Thailand. *TEI Quarterly Journal* 3 (2): 42-45.

[4] Sumrit, D. (1993). Country Report. In *Improvement of Semiarid and Highland Agriculture in Asia*. Asian Productivity Organization, Tokyo.

[5] Brown, L.R. and Wolf, E.C. (1984). *Soil Erosion: Quiet Crisis in the World Economy*. Worldwatch paper 60, Washington D.C.

[6] Lal, R., Kimble, J.M., Follet, R.F. and Cole, C.V. (1998). The potential of U.S . croplands sequester carbon and mitigate the green house effect. *Ann Arbor*, MI.pp.128.

[7] Lal, R., Kimble, J.M. and Follet, R. (1997). Land-use and soil C pools in terrestrial ecosystems. In Lal et al (Eds) *Management of Carbon Sequestration in Soils*. CRC Press New York, Washington DC.

[8] Wischmeier, W.H. and Smith, D.D. (1978). Predicting rainfall erosion losses: A guide to conservation planning. U.S. Department of Agriculture, Agricultural handbook No 537

[9] Gnanavelrajah, N., 2007. Sustainable land-use options for enhancing carbon sequestration, plant diversity and productivity: A case of Khlong Yai Subwatershed, Thailand. PhD Dissertation submitted to Asian Institute of Technology, Thailand (unpublished).

[10] FAO, (1976). *A Framework for Land Evaluation*. Soil bulletin. No. 32. Food and agriculture organization Rome.

[11] LDD, (1992). Qualitative land evaluation manual for economic crops. No. 2 . Land-use planning Section, Land Development Department, Ministry of Agriculture and Co operation, Thailand.

[12] Bonham-Carter, G.F. (1994). Geographic information system for geoscientist: Modelling with GIS. Pergamon publication, New York.