Thai J. For. 11 : 33-45 (1992)　　　　วารสารวนศาสตร์ 11 : 33-45 (2535)

EVALUATION OF SOIL EROSION SENSITIVITY USING REMOTE SENSING AND GIS : A CASE STUDY IN KANCHANABURI, THAILAND

Payattipol Narangajavana [1]
Naeem U. Khan [2]
Tin Nyein [2]
Kaew Naulchawee [2]

บทคัดย่อ

การใช้เทคนิคทางรีโมทเซนซิ่งร่วมกับระบบสารสนเทศภูมิศาสตร์ (GIS) มีประโยชน์และให้ศักยภาพสูงในการจัดการฐานข้อมูลของทรัพยากรธรรมชาติ ในการศึกษาครั้งนี้ได้นำเอาเทคนิคทั้งสองมาใช้ในการตรวจสอบหาพื้นที่ที่ยากง่ายต่อการพังทลาย ขนาด 15x15 ตารางกิโลเมตร ในบริเวณอำเภอทองผาภูมิ จังหวัดกาญจนบุรี ปัจจัยที่ใช้เป็นตัวกำหนดในการทำแผนที่ของการพังทลายได้แก่ ความลาดชัน, ความยากง่ายของดินต่อการ พังทลาย, ความหนาแน่นของการระบายน้ำ พืชพรรณที่ปกคลุม และมาตรการในการอนุรักษ์ดินน้ำ ภาพถ่ายจากดาวเทียม Landsat TM วันที่ 12 ธันวาคม 2532 ถูกนำมาแปลเพื่อให้ทราบถึงรูปแบบการใช้ประโยชน์ที่ดินและพืชที่ปกคลุมอยู่ การเก็บข้อมูลและการตรวจสอบความถูกต้องของแผนที่ได้กระทำในสนาม ปัจจัยทั้งห้าได้ถูกนำมาทำเป็นแผนที่เชิงตัวเลขและวางซ้อนทับกันด้วยระบบ GIS ผลการศึกษาพบว่า 63.5 เปอร์เซ็นต์ของพื้นที่ศึกษาเป็นพื้นที่ราบ (ความลาดชัน 0-2%) การใช้ประโยชน์ที่ดิน ส่วนใหญ่เป็นการปลูกพืชไร่โดยที่ไม่มีมาตรการอนุรักษ์ดินน้ำ แผนที่ของการพังทลายส่วนใหญ่พบว่าอยู่ในระดับต่ำและปานกลาง ซึ่งสอดคล้องกับการสำรวจในสนาม เนื่องจากมีการถางป่าทำไร่เลื่อนลอยในบริเวณเชิงเขาและเห็นร่องรอยของการกัดเซาะแบบร่อง ผู้ศึกษาจึงคาดว่าจะเกิดปัญหาการพังทลายที่รุนแรงในอนาคต

ABSTRACT

The advantage of a combination of Remote Sensing (RS) and Geographic Information System (GIS) techniques has great potential for supplying databases on natural resources management. In this study, the area 15x15 km ^{2} in Thong Pha Phum district, Kanchanaburi province was investigated for soil erosion sensitivity. Five erosion factors were used for the production of an erosion hazard map. It consists of: 1) slope gradient; 2) soil erodibility; 3) drainage density; 4) vegetation cover; and 5)

[1] Department of Forest Engineering, Faculty of Forestry, Kasetsart University, Bangkok 10903, THAILAND.

[2] Natural Resources Program, Asian Institute of Technology, Bangkok 10501, THAILAND

conservation practices. The interpretation of LANDSAT TM dated 12 December 1989 for the delineation of land use patterns provided a vegetation factor. Field trips were also conducted for map verification and data collection. The integration of these five erosion factors was performed on the digital GIS. The results showed that 63.5% of this area was flat (0-2% slope) and the land use types mostly dominated by the intensive of agricultural crops without a conservation practices. The final erosion sensitivity map mostly showed a low and moderate level which correlated very well to the field observation. Since, there are signs of rill erosion and shifting cultivation in this study area, we suggested that the serious erosion problems may occur in the near future.

INTRODUCTION

Remote Sensing (RS) technology has developed very rapidly during the past decades. It provides an opportunity to view or to analyze natural resources in inaccessible areas at any season of the year. This technology is important for acquiring information which is needed for better management of natural resources. The activities of remote sensing range from satellite data acquisition, distribution, analysis and finally map production.

Another technology, Geographic Information System (GIS), have also developed during the past decades. This technology is the data base for the combination of various geographic and/or natural resource data. The advantages of GIS in computer-readable form has great potential for supplying resource management information more than the map from remote sensing techniques. Nowadays, the resource managers need more and better resource data than ever before for considering and making resource decisions. Thus, the combinations of RS and GIS techniques is a very important tool for natural resources managers.

On the global skin, the land degradation is a serious phenomenon especially in the developing countries. The rapid birth rate of population indicates a need for more land to be brought under cultivation on all continents. Large areas of land have been destroyed and exploited for the production of products for agro-industries. This has often caused the rapid deterioration of land resources (Rimvanich, 1988). The by-product of such extensive land use is the occurrence of soil erosion problems, resulting in the deposition of sediment in rivers and reservoirs.

In Thailand, the problem of soil erosion is also of major concern. From a study carried out in 1989 by the Royal Forest Department, it was estimated that 29% of the total area of designated forest land had been encroached. Deforestation in hilly areas, where the risks of soil erosion are high, has reached disturbing proportions even only in the last decade. The importance of the proper utilization of renewable natural resource is emphasized to be a policy of numerous agencies. They are responsible for proposing the measures to implement the development of land resources including land use planning and soil and water conservation. The mapping of soil erosion is the one way to provide the information data before the planning stage. Thus, the main goal of this study is to use the application of RS an GIS techniques for producing and erosion sensitivity map. The specific objectives are: 1) to retrieve land use/land cover data from satellite data. 2) to overlay various information data by using GIS for coming out with different classes of soil erosion sensitivity.

Table 1. Some references of the application of RS and GIS for erosion mapping/assessment

References	Erosion Mapping/Assessment			
	RS techniques		GIS techniques	USLE
	Aerial photos	Satellite images		
Fenton (1982)	✓	-	-	-
Stephen and Cihlar (1982)	✓	✓	-	-
Trustrum (1983)	✓	-	-	-
Cuff and Trustrum (1983)	✓	-	-	-
Sayogo (1986)	✓	✓	✓	✓
Meyere and Putte (1987)	✓	✓	✓	-
Piyapongse (1987)	✓	✓	✓	-
Eiumnoh (1988)	-	✓	✓	-
Tiwari (1990)	-	✓	✓	✓
Ofren (1991)	-	✓	✓	✓

REVIEW OF LITERATURE

The application of remote sensing techniques for studying the erosion have been done in the past decades. Some of references are summarized in Table 1. It shows that the aerial photographs had been widely used for erosion assessment and mapping during the first era of RS and are still considered to be of great help. After the development of digital RS in various spectral signatures and more detail in ground resolution (varying from 80 meters to 10 meters), the combination of aerial photo and satellite images are also widely in used after 1986. Due to the recent development of GIS technique, this field of study has been started since 1987. The model based on a GIS, designated as a basis for soil erosion and conservation, can be able to simulate soil erosion processes and prediction of soil loss in a certain area (Loran et. al., 1988).

A large number of models for the prediction of erosion and soil loss have been designed and new developments are still in progress. One of them is the empirical approach which based on the statistical analysis of a large data set yields mathematical expressions without describing or explaining the processes involved (De Coursey, 1985). A prime example of this empirical type of model is USLE. This was developed for the midwestern United States (Wischmeier and Smith, 1978), and has been applied in many countries with varying degrees of success. Althought, statistically based models require long term recording of rainfall and soil loss data, after the establishment, this model can provide an easy and quick method for water erosion prediction (Hussein, 1987). Besides this, the modification of USLE for local conditions has been adapted by many researchers (Mutchler and Murphree, 1983; Elwell, 1979).

The USLE has been used in Thailand for over a decade (Land Development Department, 1983). The applied USLE has also been done by many researchers (Srikhajon et. al, 1984; Piyapakorn, 1981). However, most of them employed for a province in the north (Piyapongse, 1987; Harper, 1986; Omakupt et. al. 1988; LDD, 1985), the northeast (Piyapakorn, 1981) and a few of them in the eastern Thailand (Lorchareonrat, 1985).

STUDY AREA

The study area is located in Thong Pha Phum district, Kanchanaburi province, western Thailand. It is roughly between $14^{\circ}37'$ - $14^{\circ}48'$ N and $98^{\circ}35'$ - $98^{\circ}45'$ E, and traversed by the main highway route 323 between Km.102-Km.126 and Kwae Noi river (see Fig.1). The area is approximately 15x15 kilometer i.e. 225 sq. km. The annual rainfall range from 1600 to 2000 millimeters and the parent materials of this area are mostly limestone and sandstone (LDD, 1987). For the severity of soil erosion, no reports have been done in this study area. The reason may be the lesser of the rate of soil erosion than the northern region because the geographical characteristic of Kanchanaburi is located between the mountain and situated in the rain shadow area (Srikhajorn 1992, personal communication).

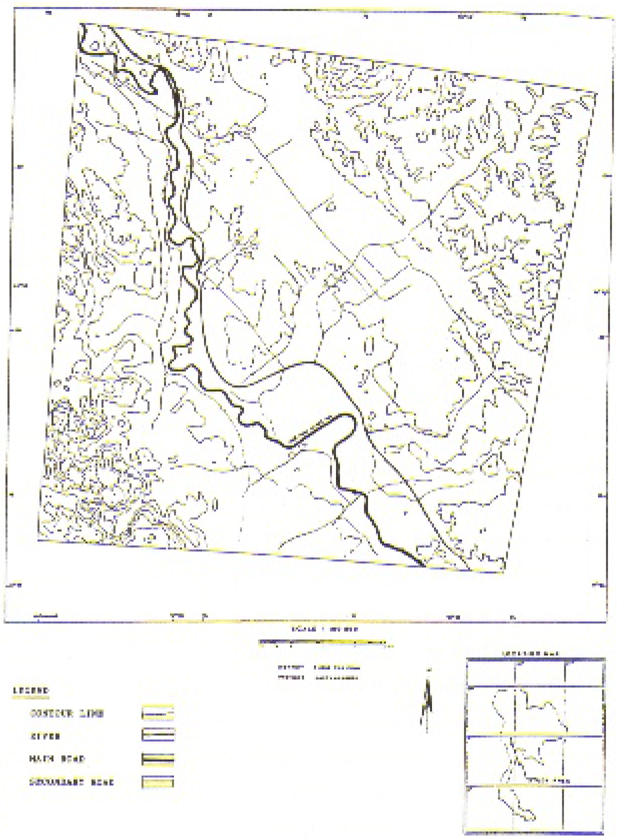
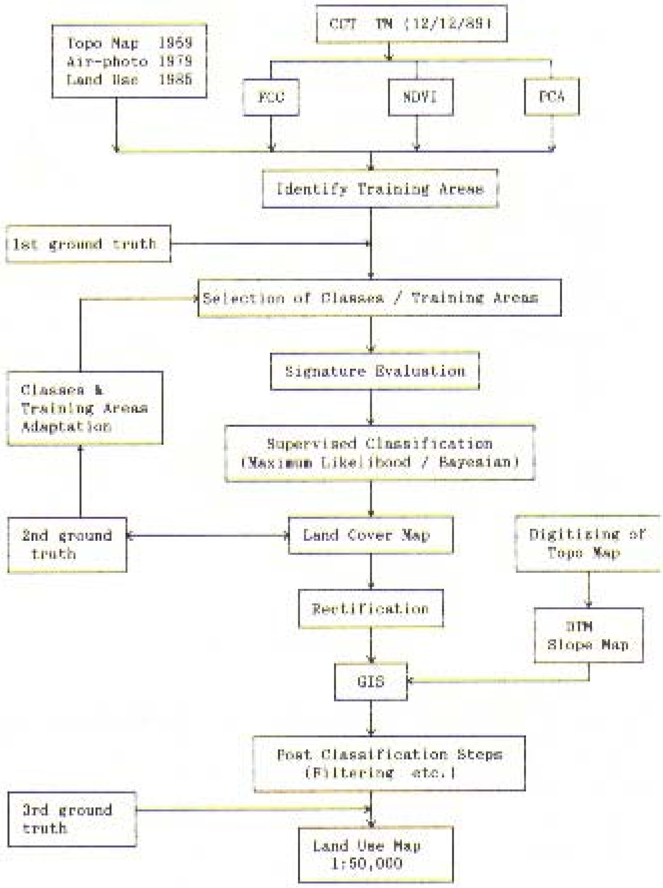


Figure 1.

Location of study area.

Figure 2. Flow chart of digital RS analysis.



MATERIALS

1. Primary data
   - LANDSAT TM data, from CCT dated 12/12/89
   - False Color Composite
2. Support data
   - Aerial photographs 1:15,000 1979
   - Topographic map 1:50,000 1969
   - Geological map 1:1,000,000 1969
   - Soil map 1:100,000 1986
   - Land use Map 1:100,000 1985

METHODOLOGY

Image processing for land use and land cover map

The detail of image processing is shown by flow chart in Figure 2. A computer compatible tape (CCT) of LANDSAT TM was analyzed by the MULTISCOPE (ver 2.0) Image Processing (IP) software to enhance False Color Composite (FCC) image, Principal Component Analysis (PCA) image and Normalized

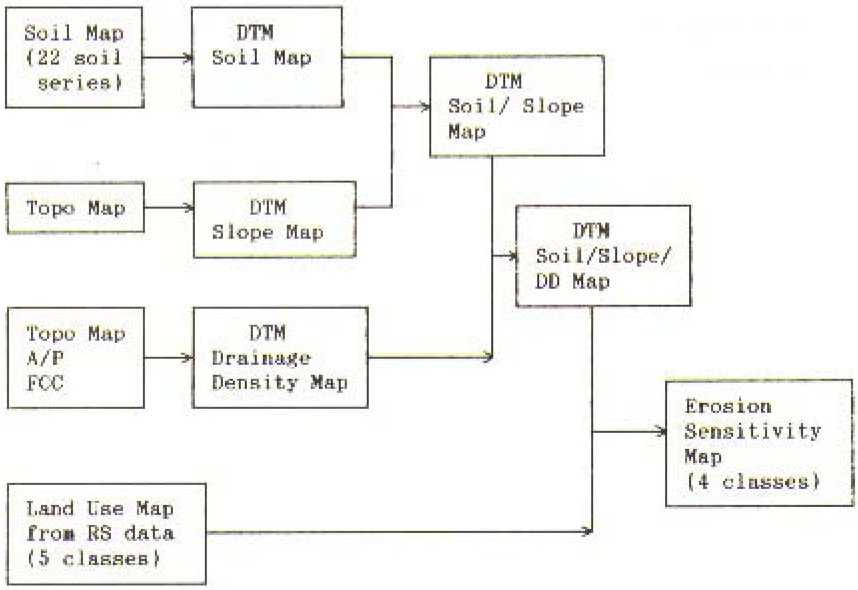


Figure 3. Flow chart of GIS overlay for erosion mapping.

Difference Vegetation Index (NDVI) image at the scale of 1:50,000. The combination of these images incorporated with the topographic map and aerial photograph assist in the selection of training area. After the first ground truth, the classification was performed using the maximum likelihood algorithm. The results of this step provided the representing 16 classes which defined by spectral signatures. However, from the second ground truth, we found the problem of misclassification. The adaptation of classes and training areas were also reassigned again. The final results of cover type were 5 classes and overlay with the DTM slope map in order to correct the wrongly classified class in a wrong place by using ERDAS (ver 7.5) IP & GIS software. After the filtering, third ground truth was done for map verification. Figure 4 shows the resulting land use/land cover map.

RS and GIS approach for soil erosion mapping

The empirical; approach like as USLE method has been used for mapping of soil erosion sensitivity in this study. Five erosion parameters are slope steepness soil erodibility, drainage density (stands for runoff erosivity), vegetation factor and conservation practices. To indentify the soil erosion sensitivity area, four base maps are needed to overlay. The methodology for overlaying each map explain by flow chart in Figure 3 by using the MATRIX program in ERDAS software.

Soil map is produced by digitizing of the soil map (1:100,000) 1986. The 22 soil series in this study area from the original source are recoded for the purpose of soil erodibility (K-factor in USLE). Based on the soil series, the soil texture was determined from the charac-

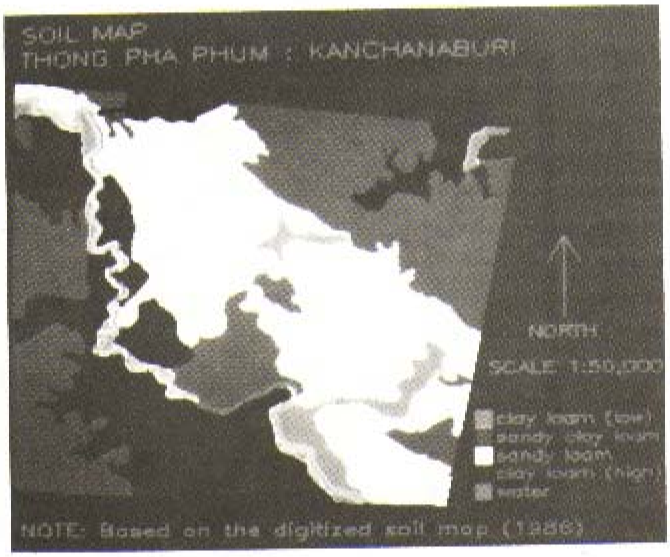


Figure 5. Soil map of the study area.

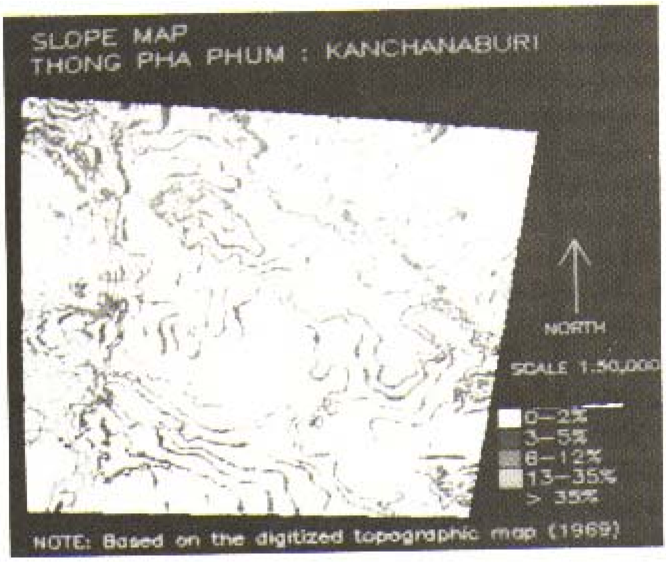


Figure 6. Slope map of the study area.

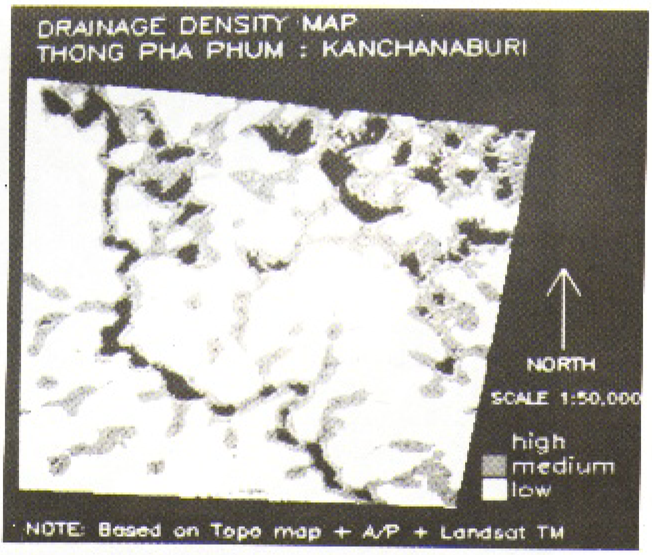


Figure 7. Drainage density map of the study area.

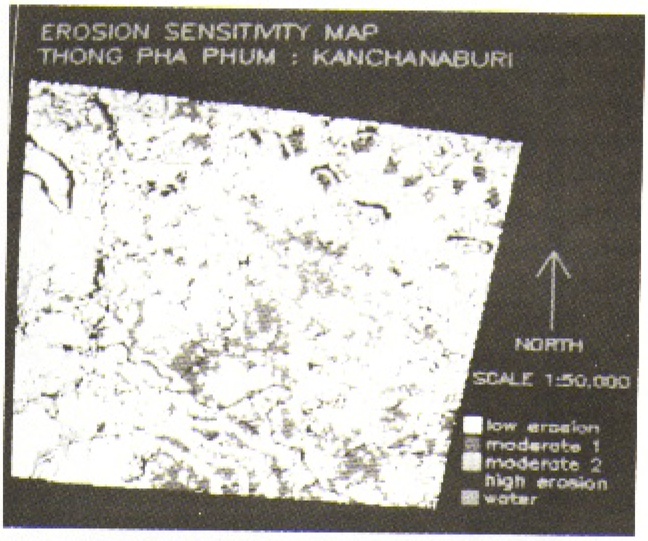


Figure 8. Erosion sensitivity map of the study area.

teristic of that soil series. And the K-value can directly obtain from the soil texture (LDD, 1983; LDD, 1987). The soil texture in the study area has only three classes, clay loam, sandy clay loam and sandy loam. For the classification, clay loam has also divided into two groups, one is a low or flat area and the other is a mountainous or undulating or hill area. Therefore, the soil map is re-classified into 4 classes as clay loam (in flat area), sandy clay loam, sandy loam and clay loam (in high, rolling area) and the K-value is 0.19, 0.20, 0.26 and 0.28, respectively, (LDD, 1983). Figure 5 shows the resulting soil map.

Slope map is produced by digitizing the topographic map (1:50,000) 1969. By using the ERDAS software, the digital elevation model (DEM) was calculated and the slope map had been produced. Five classes of slope map were determined from the basis of land use classification (LDD, 1987). It is 0-2% slope, 3-5% slope, 6-12% slope, 13-35% slope and more than 35% slope. The resulting slope map is shown in Figure 6.

Drainage density map is produced by digitizing the drainage map which made from the topographic map, aerial photograph and FCC image. Using the DEM to calculate the density of drainage, three classes were determined as low density (<40 m/ha), medium density (40-120 m/ha) and high density (>120 m/ha) The resulting map is shown in Figure 7.

Land cover map, resulted from the remotely sensed data interpretation, provided a vegetation factor (Omakupt et. al., 1988). The conservation practices factor obtained from the field observation and interview made with local residents. Finally, the erosion sensitivity map had been produced into 4 classes as low erosion, moderate 1 (stands for low to moderate condition), moderate 2 (stands for moderate to high condition) and high erosion as shown in Figure 8.

RESULTS AND DISCUSSION

RS analysis

The resulting 5 classes of land cover map from the remote sensing interpretation showed the percent of coverage are 4.2, 38.8, 26.6, 29.9 and 0.5 in orchard, bareland, farm crops, forest and water body, respectively. Bareland mostly appear in the study area following with forest and farm crops. This results are reasonable because, after the ground check, bareland and farm crops distribute all over the area along the both side of Kwae Noi river. Forest locate in the west, central north and northeast of the study area.

The results of the land cover map from this study show a high percentage of bare land. This result seem to be over estimated. However, from the field observations, we found the real problem that the bareland is not only bare soil but includes the many types of land cover/land use such as mango plantation, less healthy grassland, abandoned paddy fields, bare soil after harvested of agricultural crops. For further understanding, the results of land cover/land use classification of remotely sensed data interpretation is explained in Table 2. The bare soil interpretation includes the mango plantation, grassland, teak plantation, fallow land and bare soil due to the crop harvest. This result can be explained by the percent of leaf cover is less (such as mango is 14% of the vegetation cover). However, the mango plantation on the large area located in the central north of the study area. Thus, we can classify the orchard categories. In case of the teak plantation, we already classify to the one category, but the result indicates over estimation due to the distribution along the mountain area. So, we reclassify in the forest category. For the category of farm crops, it show in the type of mixed vegetation in healthy condition. Then, we can classify in the other group. The problem of this results is the bare land after harvested crops. This area should classified as a farm

Table 2. Color in FCC, PCA and NDVI From RS analysis.

Land cover Land use	Color in			Final classify
	FCC	PCA	NDVI	
Bare soil				
- mango plantation	dark green	dark blue	black	Orchard
- grassland	blue green	red pink	black	
- teak plantation	light blue	red	grey	
- fallow land	white	pink	light grey	Bareland
- after harvested	light blue	pink	black	
Dry dipterocarp forest	red	dark blue	light grey	
Mixed deciduous forest	red	green	black	Forest
Mixed vegetation	dark green	pink	light grey	
- orchard, cotton, sugar cane, corn etc.				Farm crops

crops. In this stage, the techniques of spectral signatures for making the more contrast between the bare soil (fallow land) and bare soil (after harvested field crops) is needed to solve this problem as possible as it is. After the clearance of this problem, the percent of bare land will reduce and the percent of farm crops increase which it is reasonable from the field observation.

GIS analysis

The resulting 5 classes of slope map showed the percent of each slope classes as 63.5, 16.2, 12.4, 7.2 and 0.7 in 0-2, 3-5, 6-12, 12-35, >35% slope, repectively. It indicates that this area are mostly flat (0-2% slope).

The percent of each soil classes in soil map (Fig.5) are 6.4, 33.1, 33.1, and 25.8 in clay loam (low), sandy clay loam, sandy loam and clay loam (high), respectively. Most of soil texture are sandy clay loam and sandy loam which locate in the mountain and hillslope area. Clay loam also find along the river and the undulating area.

The three classes of drainage density map in Figure 7 showed the percent of each classes as 58.2, 31.1 and 10.7 in low, medium and high drainage density. It indicates that this area is mostly low drainage density.

From the erosion sensitivity map, the results indicate that 35.9% of this study area is in low erosion sensitive, 39.1% in the moderate 1 condition, 17.9% in the moderate 2 condition and 7.1% in the high erosion. Mostly high erosion sensitive area locate in the west side of Kwae Noi river because of the high degree of slope and intensive land use (shifting cultivation). The steep slope on the northeast of study area is also high erosion sensitive area (see Fig.8). However, all of the study area can assume in the low and moderate I condition. This results agreed very well with a field observation because there are no severely eroded areas in this field study. From the ground check, we found that all of the areas did not have any soil conservation practices. The local people mostly plough the soil (tillage) up and down along the slope. Especially in the western part of Kwae Noi river, there are intensive agricultural land use and a signs of rill erosion can easily see on the steep slope of bareland that it can consider as a sensitive sites to erosion and need a conservation measures.

CONCLUSIONS

1. The combination of RS and GIS provide a good results of mapping soil erosion. However, if SPOT data or combination of the SPOT data and LANDSAT TM data in multidate is used, it may yield better results on land use mapping and consequently, the effective monitoring of soil erosion.

2. The soil management practices and other conservation measures in this area are negligible that indicate the lack of soil conservation extension. The main features of mismanagement include shifting cultivation along the slope, land clearing. We have the opinion that if appropriate attention is not given to the soil conservation extension and if control is not achieved over the shifting cultivation these two problems may change into the real big issue before the next decade.

3. There are no severely eroded areas in this study area, however, we have the opinion that there are considerable sites in the area which are sensitive to erosion due to the lack of soil conservation practices and intensive land use. There are also a signs of rill erosion which if not controlled at the right time, may develop into a serious problem.

ACKNOWLEDGMENT

PN. would like to thank US-ASEAN for providing the scholarship to be trained at AIT and making this study possible. His gratitude is also extended to the staff of Remote sensing Laboratory Natural Resources Program, for the excellent training and continuous assistance.

REFERENCES

Cuff, J. and N. Trustrum, 1982. An evaluation of aerial photographs for mapping south island high *country vegetation and erosion.* pp 185-194. ***In*** *Remote Sensing for Soil Conservation* (Work shop Proc. 29 Jun - 1 Jul 1982): A Remote Sensing Manual for Soil Conservators. Ed. by P.R. Stephens., Wellingtons.

De Coursey, D.G. 1985. *Mathematical models for non - profit water pollution control. J. of Soil and Water Cons.* pp. 409-413.

Eiumnoh, A. 1988. Erosion estimation of granitic derived soil by remote sensing techniques. pp. 387-396. ***In*** *Proc. 5th Int. Soil Cons. Conf.* Land Conservation for Future Generations, 18-29 Jan 1988. Bangkok, Thailand.

Elwell, H.A. 1979. Modelling soil losses in Zimbabwe *Rhodesia*, Paper presented at the 1979 summer meeting of ASAE and CSAE, Winninpeg, Canada. (Paper 79-2051)

Fenton, T.E. 1982. Estimating soil erosion by remote *sensing techniques*. pp. 217-231. **In** Remote Sensing for Resource Management. Ed. by C.J. Johannsen and J.L. Sanders. Soil Conservation Society of America, Iowa.

Harper, D.E. 1986. Sustainable agriculture on slopes: The effectiveness of international development projects in fostering soil conservation in north Thailand. Ph.D dissertation. Honolulu, HI. Dept. of Geography. Univ. of Hawaii.

Hussien, M.M. 1987. Water erosion in areas with limited data. **In** Proc. 4th Int. Conf. on Soil Cons., I. Pla Sentis (ed.) Moracay, Venezuela.

Land Development Dapartment. 1983. The application of universal soil loss equation and soil conservation measures. Land Development Department, Bangkok. 266 p.

Land Development Department. 1985. The application of Landsat data for study on the factors which could cause the impact on the quality of Mae Cham watershed, Chiang mai province, Bangkok, Ministry of Agriculture and coopertives.

Land Development Department. 1987. Land use planning in Kanchanaburi province. Land Use Planning Division. 305 p.

Lochareonrat, D. 1985. A comparative study on soil loss from experimental plots and the use of universal soil loss equation in the eastern basin. Kaelang, Rayong province, M.Sc. Thesis Kasetsart Univ. Bankok.

Loran, T.M., J.A. Zinck and K.J. Beck. 1988. Management, conservation and erosion data base. pp. 37-62. **In** Proc. 5th Int. Soil Cons. Conf. Land Conservation for Future Generations. 18-29 Jan 1988, Bangkok, Thailand.

Meijere, J.C. De and Putte, R.A Wande. 1987. The role of information systems in natural resource management. ITC Journal 1987-2, pp. 129-133.

Mutcheler, C.K. and Murphree, C.E.Jr. 1983. Experimentally derived modification of USLE. **In** Proc. Int. Conference on Soil Erosion and Conservation. S.A.El Swaify, W.C. Moldenhauver and A. Lo(eds.) pp. 523-527.

Ofren, R.S. 1991. A comprehensive agroforestry approach for the ecological development of upland community and their watershed. A case study of Nong Luang watershed, Amphoe Umphang, Tak province, Thailand. M.Sc. Thesis AIT, Bangkok. 94 p.

Omakupt, M., P. Impat, N. Kanchanakul and D. Buapradapkul. 1988. Soil erosion mapping in the Chiang mai basin using remote sensing data and geographic information system. pp. 159-167 **In** Proc. Final seminar under the CIDA-Thailand Landsat Project, Chiang Mai, Thailand, Dec 1988.

Piyapakorn, P. 1981. Quantitative analysis of soil erosion in Changwat Buri Ram by using universal soil loss equation. M.Sc. thesis Srinakharinwirot Univ. Bangkok. 183 p.

Piyapongse, P. 1987. The application of landsat imagery to soil erosion study in northern Thailand. pp. q 18.1-q 18.5. **In** Proc. of The Asian Conference on Remote Sensing, Jakarta, Indonesia.

Rimwanich, S. 1988. Soil conservation strategies in the context of a shrink resource base. pp. 1-10. **In** Proc. 5th Int. Soil Cons. Conf. Land Conservation for Future Generations. Bangkok, Thailand.

Sayogo, J.M. 1986. Small scale erosion hazard mapping using Landsat information in the northeast of Argentina. pp. 669-674. **In** Sym. on Remote Sensing for Resources Development and Environmental Management. Enschede, Aug 1986.

Srikhajon, M., A.Somrang, P. Pramojanee, S. Pradabvit, C. Aneeksamphant. 1984. Application of universal soil loss equation for Thailand. **In** Soil Science as a Tool for Rural Development . Bangkok. ASEAN.

Stephen, P.R. and J. Cihlar. 1982. Mapping Erosion in New Zealand and Canada, pp. 232-242. **In** Remote Sensing for Resource Management. Ed. by C.J. Johannsen and J.L. Sanders. Soil Con servation Society of America, Iowa.

Tiwari, D.N. 1990. Watershed modelling: Estimation of surface runoff and soil erosion rates. A case - study of Nakkhu Khola Watershed, Nepal. M.E. the-
sis, AIT, Bangkok. 83 p.

Trustrum, N. 1983. The use of aerial photographs for erosion identification and assessment. pp. 95-102. In Remote Sensing for Soil Conservation (Workshop Proc. 29 Jun - 1 Jul 1982): A Remote Sensing Manual for Soil Conservators. Ed. by P.R. Stephens., Wellingtons.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses: A guide to conservation planning. Agricultural Handbook No.537. Wash ington D.C., USDA.