INTRODUCTION
The land cover changes due to human land use activities are regarded as the main reason for global environmental change, so the study on them becomes the forefront and hot spots of research to scholars. Land use/land cover and human/natural modifications have largely resulted in desertification, biodiversity loss, global warming and increase of natural disaster-flooding. Remote sensing becomes useful because it provides cost-effective multi-spectral and multi-temporal data, and turns them into valuable information for understanding and monitoring land development patterns and processes and for building land use and land cover data sets. GIS is the technology which has been used to view and analyze data from a geographic perspective. GIS technology provides a flexible environment for storing, analyzing, and displaying digital data necessary for change detection and database development. Remote sensing and Geographical Information System (GIS) are well-established information technologies, the value of which is now widely recognized for applications in land and natural resources management.

Soil loss has been considered as the primary cause of soil degradation since soil loss lead to the loss of topsoil and the soil organic matters which are essential for the growing of plants. Moreover, the erodent soil can be transported and accumulated in the water body which cause the water body more shallow and cannot store the required amount of water. Therefore, the soil loss can impact on the reduction of crop productivity. In order to assess the amount of soil loss per area per year, the Universal Soil Loss Equation (USLE) has been the most widely used tool in the world. According to the USLE, the amount of soil loss can be determined by the multiplication of six factors involved climate, soil property, topography, land cover, and conservation practice. Although there are many factors influence on soil erosion, many researches stated that the plant cover and land use

EVALUATION OF IMPACTS OF SPATIAL LAND USE CHANGES ON SOIL LOSS USING REMOTE SENSING AND GIS IN HUAY SAI ROYAL DEVELOPMENT CENTER, THAILAND

Saowanee Wijitkosum
Environmental Research Institute Chulalongkorn University, Bangkok (THAILAND)
E-mail : i_am_saowanee@hotmail.com

Received October 5, 2011 Accepted February 20, 2012

ABSTRACT
By using two period remote sensing images and with the support of GIS and RS, spatial pattern of land use change of Huay Sai Royal Development Centre, Thailand in recent 10 years is interpreted and extracted, and elucidated that human activities are the driving force for changes of cultivated land. The impacts of land use changes on soil loss have been assessed by applying the Universal Soil Loss Equation (USLE). The change of land use types in the study area over the period of 2000 - 2010 was investigated by applying remote sensing technique and field survey for interpreting the satellite image taken by Lansen-5 TM. The study revealed that the change of land use types over 2000 - 2010 period affect the protective function of the land. The increase of forest area and the decrease of opened land led to the reduction of soil loss risk by raising the protective function of the land. During 2000 to 2010, the area with soil loss more than 125 Mg ha\(^{-1}\) per year decreased obviously from 44.12% to 0.19% of the total area.

Key Words : Relative land use change, Soil loss, Universal soil loss equation, Huay Sai Royal Development Centre, Land
have been considered as the most important factors that affect on the intensity of soil erosion. The changes of land use such as deforestation or substitution of forest by crop have led to a dramatic increase in soil erosion due to the disappearance of land covering material. On the other hand, the increase of forest area or other land covering material can probably reduce the amount of soil loss. Vegetation controls soil erosion by means of its canopy, roots, and litter components, erosion also influences vegetation in term of the composition, structure, and growth pattern of the plant community. Loss of vegetative cover may lead to the formation of soil seals that increase runoff and erosion during the early stages of seal development.

**AIMS AND OBJECTIVES**

The objectives of this study are to investigate the land use changes, assess the risk of soil loss and also analyse the impact of land use changed on soil loss in the study area.

**STUDY AREA**

In this study, the desertification risk assessment was conducted at Huay Sai Royal Development Study Centre area, where locate in Cha-am District, Petchaburi Province, Thailand. The site covered 1,841 ha. Before 1983, it was the plentiful area afterward the local people invaded this area for monoculture farming i.e. pineapple farming and applying the chemical pesticide. It caused this area faced the depleted soil and top soil loss problems. The soil became hard and compact. After King Bhumibol visited the site in 1983, his majesty made a comment for the recovery of this area under the Huay Sai Royal Development Study Centre Project. The restoration of this area covered 3 sections i.e. natural resource restoration, water resource development and quality of living of local people development including the creation of knowledge and realization of an important of natural resource in order to meet the sustainable mutual living between human and nature.

**METHODOLOGY**

**Land use changes investigation**

Both remote sensing technique and field survey were applied for interpreting the satellite image taking by Lansat 5 TM in order to investigate land used of the study area in 2000 and 2010. The raw spatial data and satellite images used in the research came from Geo-Informatics and Space Technology Development Agency (GISTDA). This information was analyzed with ARCGIS and remote sensing technology. The images were imported into ERDAS Imagine Image Processing Software for further processing. Since the images were in single bands, layer stack technique was performed to group the bands together. This was followed by performing further geometric corrections of the images to remove few scattered clouds in the image. Both images were projected to the Universal Traverse Mercator (UTM) coordinates zone 47. The spheroid and datum was also referenced to WSG84. The images were later displayed as false-color composites with band combination of red as band 7, green as band 4, and blue as band 2.

**Soil loss assessment**

The assessment of soil loss risk was determined base on the factors defined by the USLE. The USLE evaluates the long-term average annual soil loss (A) by sheet and rill loss. The USLE is defined as

\[
A = R \cdot K \cdot L \cdot S \cdot C \cdot P
\]

where A is average annual soil loss (mass area\(^{-1}\) per year), R is the rainfall and runoff erosivity factor, K is the soil erodibility factor, L is slope length factor, S is slope steepness index, C is land cover/management factor and P is soil conversation factor. In Thailand, Land Development Department (LDD) has adjusted and validated this model to be appropriate to the local condition. According to the study of LDD (2000), each factor can be defined as follows. The rainfall and runoff erosivity (R) is determined as a function of total storm kinetics energy (E) and its maximum 30-min intensity (I\(_{max30}\)). Due to this definition, LDD (2000) has developed many equation and then proposed an equation which is suitable for amount of rainfall in Thailand that is

\[
R = 0.4669 \times 12.1415
\]

where R is rainfall and runoff erosivity (mg ha\(^{-1}\) per year) and X is average annual rainfall (mm
The average annual rainfall of the study area was calculated based on the 30-year period (from 1981 to 2011) rainfall which is collected from the adjacent weather station. The soil erodibility factor (K) is a quantitative description of the inherent erodibility of a particular soil, it is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. The K factor is determined corresponding to the top soil property, land form and physiographic and also considered the geography of the area. They also developed a table indicating the general magnitude of the K-factor as a function of organic matter content and soil textural class. If site inspection or data analysis indicate significant variations in the soil erodibility, different K factors can be assigned to different areas of the site. The soil erodibility factor ranges in value from 0.02 to 0.69. The national database of K factor which was provided by LDD (2000) can be summarized that K factor of soil in Thailand range from 0.04 - 0.56.

The slope length factor (L) is expressed as the ratio of expected soil loss to that observed for a field of 22 m length. In USLE, L factor is given by

\[ L = \left( \frac{\lambda}{22.13} \right)^m \]  

(3)

where \( \lambda \) is the distance from the onset of overland flow to the deposition occurs or when runoff enters a channel that is bigger than a rill. In the USLE, \( m \) varies with slope gradient. It has a value of 0.2 for gradients of less than 1% and increase to a value of 0.7 for gradient greater than 21%. The slope steepness index (S) is the ratio of expected soil loss to that observed for a field of specified slope of 9%. If gradient is less than or equal to 9%, the S factor in USLE is given by

\[ S = 0.065 + 0.045s + 0.0065s^2 \]  

(4)

while if gradient is greater than 9%. The S factor is given by

\[ S = 6.4\{\sin[\tan(s/100)]\}^{0.75}\{\cos[\tan(s/100)]\} \]  

(5)

where \( s \) is % slope.

The national database of both L and S factors for all slope gradients corresponded to soil series found in Thailand have been summarized by LDD as LS factor. The LS factor of land in Thailand ranges from 0.226 - 4.571. The land cover/management factor (C) is an index for the protective coverage of canopy and organic material in direct contact with the ground. It is measured as the ratio of soil loss from land cropped under specific conditions to the corresponding loss from tilled land under clean-tilled continuous fallow conditions. High values of C factor occur on bare land while low values are found in area of dense forest or grain cover. Therefore, the change of land use types can affect on the C factor. The national database for C factor proposed by LDD showed that the C factor ranges from 0.001 (Tropical Rain Forest) to 1.000 (bare land). While most regions in Thailand have no conservative practice management therefore the P factor has been defined as 1.0.

The impact assessment of land use changes on soil loss

In order to assess the impacts of land use changes on soil loss, ArcGIS was applied as a tool for database management. All relative data and required database was classified and input to ArcGIS for calculation of soil loss per year.

RESULTS AND DISCUSSION

Land use types and its changes

By applying the remote sensing technique for interpreting the satellite image taking by Lansat 5 TM in 2000 and 2010 revealed that the land use in the study area could be classified to 5 types as follows:

1. Forest area including deciduous dipterocarp forest whose dominant plant are iron wood, siamese sal, shorea and Dipterocarpus and covering planted forest and forest park.
2. Deteriorated forest whose dominant plant are as same as the forest area but more arid and the density of green area is lower.
3. Community and agricultural area where most of agricultural area is monoculture plant such as pineapple.
4. Opened area covering the non-vegetation area.
5. Water body covering natural and man-made water body.

According to the land use study of the two periods, it discovered that the largest area of the site in 2000 and 2010 were forest area which covered...
49.5% of total area, and forest area which covered 67.8% of total area, respectively. Details of land use of the site are shown in Table 1 and Fig. 1.

It can be summarized from Table 1 that in 2010 the forest area increased 36.84% when compare to the forest area in 2000 while the opened area decreased 78.51%. On the other hand, this can imply that the overall protective function of land cover increased during the 2000 to 2010. In addition, the spatial changes of land use types from 2000 to 2010 were investigated as showed results in Table 2. It revealed that forest area in 2000 became deteriorated forest (11.31%), community and agricultural area (6.34%) and opened area (0.54%) in 2010. Moreover, deteriorated forest area in 2000 became forest area (67.40%), community and agricultural area (7.53%) and opened area (1.62%) in 2010. Furthermore, community and agricultural area in 2000 was changed to forest area (38.60%), deteriorated forest (12.31%) and opened area (1.09%) in 2010. Beside, opened area in 2000 was change to forest area (64.98%), deteriorated forest (31.61%) and community and agricultural area (2.04%) in 2010. The changes of water bodies area was neglected because water bodies area was not considered in soil erosion risk assessment.

Table 1: Land use of the site in 2000 and 2010

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (ha)</th>
<th>Relative change of land use (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In 2000</td>
<td>In 2010</td>
</tr>
<tr>
<td>Forest area</td>
<td>912.18</td>
<td>1248.69</td>
</tr>
<tr>
<td>Deteriorated forest area</td>
<td>551.84</td>
<td>297.32</td>
</tr>
<tr>
<td>Community and agricultural area</td>
<td>119.59</td>
<td>158.93</td>
</tr>
<tr>
<td>Open area</td>
<td>120.63</td>
<td>25.91</td>
</tr>
<tr>
<td>Water body</td>
<td>137.23</td>
<td>110.61</td>
</tr>
<tr>
<td>Total</td>
<td>1,841</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1: (a) Land use of the study area in 2000 (b) Land use of study area in 2010
Soil loss risk in the study area

The assessment of soil loss risk in the study area by applying USLE revealed that very high soil loss risk category (>125 mg ha\(^{-1}\) per year) occupied most area in 2000 (812.51 ha) while low soil loss risk category (0 - 12.5 mg ha\(^{-1}\) per year) occupied most area in 2010 (1505.94 ha) as see in Fig. 2. During 2000 to 2010, the area with soil loss more than 125 mg ha\(^{-1}\) per year decreased obviously from 44.12% to 0.19% of the total area. On the other hand, the area with soil loss 0 - 12.5 mg ha\(^{-1}\) per year increased significantly from 7.53% to 81.78% of the total area.

Table 2: Area of land use change during 1990 to 2010 period

<table>
<thead>
<tr>
<th>In 2000</th>
<th>Forest (ha)</th>
<th>Deteriorated forest (ha)</th>
<th>Community and agricultural area (ha)</th>
<th>Opened area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest (ha)</td>
<td>735.938</td>
<td>103.190</td>
<td>57.817</td>
<td>4.930</td>
</tr>
<tr>
<td>Deteriorated forest (ha)</td>
<td>371.920</td>
<td>124.743</td>
<td>41.553</td>
<td>8.963</td>
</tr>
<tr>
<td>Community and agricultural area (ha)</td>
<td>46.165</td>
<td>14.726</td>
<td>55.548</td>
<td>1.301</td>
</tr>
<tr>
<td>Opened area (ha)</td>
<td>78.391</td>
<td>38.128</td>
<td>2.460</td>
<td>1.510</td>
</tr>
</tbody>
</table>

The impact of land use changes on soil loss

After Huay Sai Royal Development Study Centre has been established since 1983, the area under this centre has been rehabilitated by forestation and rising awareness of people, who live in this area, to value highly in the natural resource\(^{13}\). For this reason, the comparison of forest area in 2000 and 2010 showed the significant increase from 912 ha to 1248 ha as shown in Table 1. Moreover, the opened area in 2000 and 2010 obviously decreased from 121 ha to 26 ha. According to the assessment of soil loss risk by applying USLE, the very high soil loss risk category in 2010 significantly reduced when...
compared to in 2000. The soil loss risk changes corresponded to the land use changes over 2000 - 2010 period. Since, C factor in USLE directly depend on land use/land cover, the change of land use type had a significant influence on soil loss risk. Therefore, the increase of forest area over 2000 -2010 period, which raise the protective function of the land, have led the reduction of soil loss risk. This result conform to many researches stated that the deforestation and substitution of forest by crop or decreasing the protective function of the land have led to a dramatic increase in soil loss which can impact to the soil productivity\textsuperscript{10-11}.

The effect of land use types on runoff and soil loss can be explained in various ways. First of all, vegetation canopy was thought to play a key role in protecting surfaces from loss. Secondly, the litter production and organic matter accumulation could reduce soil-water loss. Litter not only directly protects the surface soil from splash loss, weaken the kinetic energy of raindrop, and slows runoff velocities, but also conserves surface rainwater due to its strong moisture holding capacity. Lastly, roots may form a dense network; such as grass root in topsoil, that physically binds soil particles, and soil-root matrix has proven to be stronger than the soil or roots separately\textsuperscript{22, 23}.

CONCLUSION

This study revealed that the land use changes in Huay Sai Royal Development Study Centre area over 2000 - 2010 periods has led to the change of soil loss risk. The assessment of soil loss risk in the study area by applying USLE Model, C factor in USLE directly depend on land use/land cover, the change of land use type had a significant influence on soil loss risk. Difference land use types in the term of size and pattern area has influenced on soil erosion risk in Huay Sai Royal Development Study Centre. The area with less land cover obviously showed the high-risk of soil erosion than the more land cover did. The increase of forest area and the decrease of opened land in the study area have obviously reduced the soil loss risk by raising the protective function of the land. Therefore, in order to prevent the soil loss, the land cover management and soil conservation measures are highly recommended to be implemented widely. Furthermore, soil conservation measures were both mechanicals measures; such as contour cultivation, tied ridging, bedding and terracing, and vegetables measures; such as cover cropping, mulching, intercropping and vertiver grass growing. Moreover, the strict enforcement and implementation of soil erosion prevention measures are the most important method to efficiently prevent soil erosion.

ACKNOWLEDGEMENT

This research was funded by the Higher Education Research Promotion and National Research University Project of Thailand, Office of the Higher Education Commission (CC315A). The Seatleites image was supported from Geo-Informatics and Space Technology Development Agency (GISTDA). The author is grateful for multidisciplinary data and information which has been collected from various sources, both in the local offices and in the central offices. And special thanks to Huay Sai Royal Development Study Centre for deep information.

REFERENCES

5. Zhou Q., The integration of GIS and remote sensing for land resource and environmental


