INTEGRATION OF GIS AND RS AS A TOOL FOR LAND USE PLANNING IN A WATERSHED

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Abstract: The effect of land cover changes to soil erosion has been mentioned but has not been applied effectively in the land use planning in Viet Nam. Technically, the main difficulties of the applying process are: how to quantify the land cover changes and how to measure its effect in soil erosion? Integration of GIS and RS can be considered as a method to include the soil erosion issue in land use planning. The land use planning can be split to 3 main tasks to answer the question: where (need to be changed), how (it could be changed) and what (is the reasonable way to change). However, the answer requires information integrated from many sources: natural condition and socio-economic condition. In the conception of reducing soil erosion based on the effect of land use change, this study use a GIS modeling to answer each question and combine to get land use planning map. The land cover changed is detected by digital image processing of satellite image. The effect of land cover change to soil erosion is analyzed timely, spatially in GIS. Based on the effect, GIS spatial modeling is applied to answer each question of the land use planning. This method has applied to Tra Khuc watershed in central of Viet Nam.
Keyword: soil erosion, land use planning, spatial analysis

1. Introduction

One of the factors that effects to the suitable land use is soil erosion which has mentioned by several authors. The soil erosion is problem in the top of 11/12 Asia countries in the list of reasons of soil degraded (conference organized by FAO at 1991). However, soil erosion needs to be considered under many aspects, at many levels and by using information from history to present [2].

Geographical approach, the soil erosion is affected by many factors which can be listed: land cover, rainfall, soil, topography. Accordingly, based on these factors, human can impact to control soil erosion. In the scale of watershed, vegetation cover is only one which human can change to reduce the soil erosion. To improve the percentage of vegetation cover in a watershed scale, land use planning (LUP) should be considered a key tools and to link with the soil erosion issue, it requires an analysis of relation between soil erosion and land cover change which can be done by building a GIS based model [3].

This paper aims to build a model to control soil erosion in broad scale. Accordingly, it needs to analyze the relation between the land cover change and soil erosion spatially.

The land cover change of Tra Khuc watershed (study area, see figure 1) is recognized by analysis of multi-temporal set of LandSat imageries. The spatial model is built and analyzed by GIS.

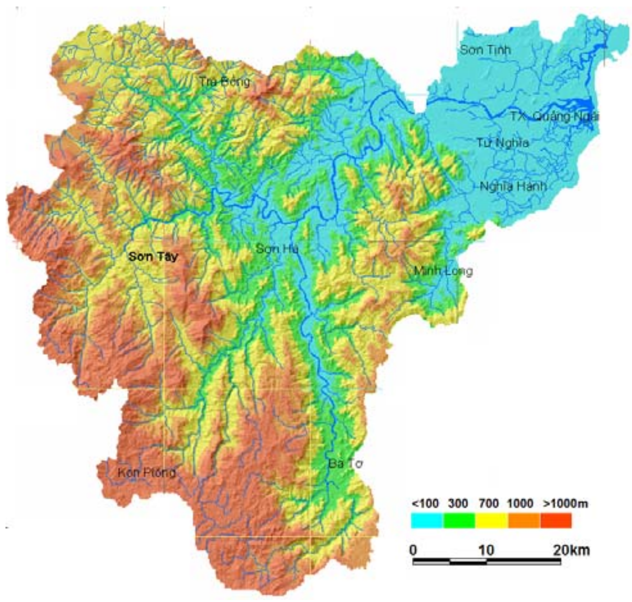

Figure 1. Tra Khuc watershed

The Tra Khuc watershed has been chosen as study area due to it's rapidly change in land cover over a high potential soil erosion.

2. Effects of Land Use Planning to Soil Erosion

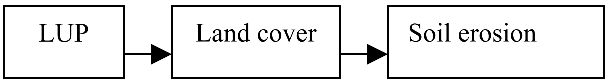

Figure 2. How LUP can effect to soil erosion

Generally speaking, the land use planning (LUP) will effect directly to the land use then change the land cover in terms of type and canopy. At its turn, land cover effects to the soil erosion in both two ways: decreasing and increasing depends on the type of land cover change.

Place the land resource of mountainous watershed such as Trà Khúc and base on the hypothesis that the main reason of land degraded is soil erosion, we can find that the solution of reduce soil erosion to remove all area of very critical soil erosion is land use planning. Naturally, beside land use planning there are many technical solution which can be applied to reduce the soil erosion. In the scale of watershed, all the technical solution can not be applied for whole watershed and they should be a part of general solution – land use planning. In the factors listed in the USLE (Universal Soil Loss Equation), the C factor (factor of vegetation cover) is only one which is human can change to reduce the soil erosion [2].

The percent of vegetation cover is higher, the soil erosion is lower [2]. Increasing the vegetation cover in watershed should be the purpose of land use planning in order to protect soil resource out of erosion progress. Then, the question of the land use planning issue is "*how the land cover change to reduce soil erosion?*" and the answer can be found in analysis of the effect of land cover change to soil erosion.

Table 1. Effects of land cover change to Soil erosion change in Trà Khúc watershed. Number in the table show the percentage of area with total area of land cover change is equivalent to 100%.

Land use change	Soil erosion change									
	1989-1997					1997-2001				
	good reduce	reduce	increase	critical increase	no change	good reduce	reduce	increase	critical increase	no change
Reforestation	1.3	6.9	0.0	0.0	0.0	2.6	16.0	0.0	0.0	0.0
Afforestation	0.1	1.0	0.0	0.0	0.3	0.9	4.6	0.0	0.0	0.7
Forest decrease	0.0	0.0	2.7	2.2	0.2	0.0	0.0	1.9	0.9	0.1
Forest loss	0.0	0.0	0.6	12.0	3.1	0.0	0.0	0.8	9.9	1.0
Others	0.2	10.3	22.1	3.8	31.6	1.0	21.6	14.5	1.2	22.3

Land cover change information of Trà Khúc watershed has been collected from satellite images. Series of three LandSat TM image dated 1989, 1997 and 2001 has been processed digitally to get the picture of land cover change in the watershed. In order to analyze the effect of land cover change to soil erosion spatially and timely, the soil erosion map of three dates (1989, 1997 and 2001) were overlaid to get the change in the soil erosion. With the supposing that all the erosion factors are not change except the land cover, the change of soil erosion is displayed the effect of the change of land cover. Accordingly, analysis the change of soil erosion under change of land cover can be used for pointing out the effect of the land cover change to soil erosion.

The effect of land cover change to soil erosion has analyzed spatially and timely from 1989 to 2001. The soil erosion change is shown on table 1 is result of effect of land cover change to soil erosion temporally.

Based on the change of land cover, the change of C factor has been calculated and then applied to USLE to calculate the change of soil erosion. The result of change C factor map as well as change of soil erosion map is numeric value. To analyze the effect of land cover change to soil erosion, both land cover change and soil erosion change were categorized. Land cover change has categories: reforestation, afforestation, forest decrease, forest loss and others. The changes of soil erosion are categorized to: good reduce soil erosion, reduce soil erosion, increasing soil erosion, critical increase soil erosion, no change.

3. Intergration of GIS and RS for Land Use Planning

Figure 3 shows the integrated of RS and GIS in land use planning for reduce soil erosion. RS used to map the present land cover as well as land cover changes. The land cover change overlaid on the soil erosion to analyze its effects. Based on this result, the GIS is used to analyze the spatial modeling to get the information needed of planning process.

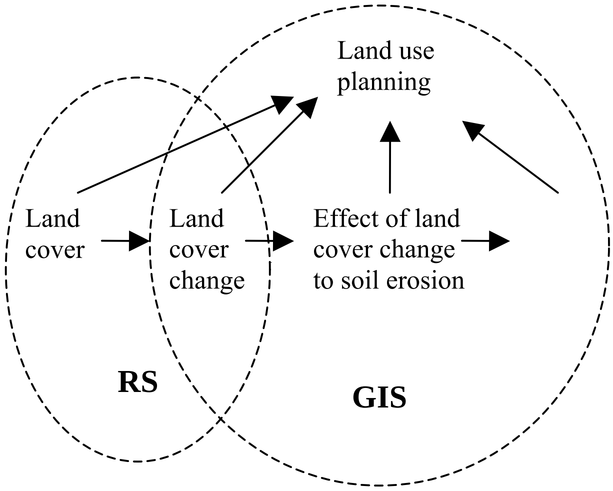

Figure 3. Integrated RS and GIS

There are two ways of approaching the change of soil erosion analysis: absolute and relative value of soil loss. The absolute value shows the quantities difference of soil loss between two compared dates while the relative value show the quality (or percentage) of soil loss change. In this study, both ways of analyses were used based on the particular condition of soil erosion in each site. In sites where soil erosion change bigger than 20%, the absolute soil erosion will be analyzed and on the other hand, in sites where soil erosion change bigger than 50 T/ha.year, the relative soil erosion will be considered.

The question above can be split to three other more specified questions: “Where need to be intervened?”, “When need to be intervened?” and “What need to be done?” [3].

As the purpose of land use planning is for control soil erosion in a watershed, a spatial analysis model to analyze the effect of land cover change to soil erosion to answer of that three questions has been built. The model is shown on the figure 4.

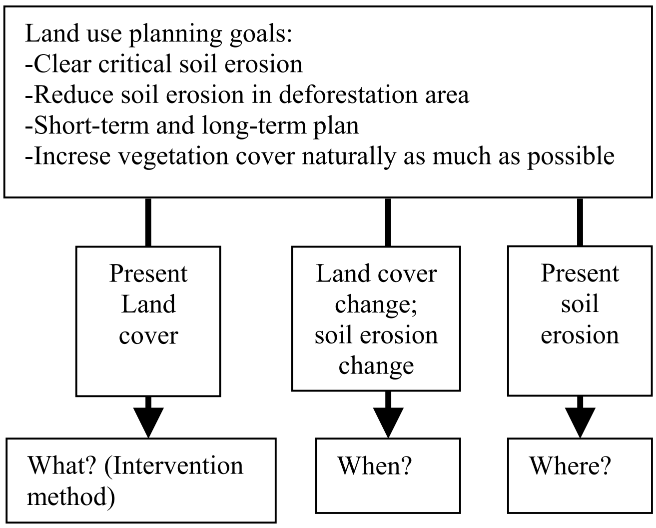

Fig. 4 Spatial analysis effect of land cover change to soil erosion for land use planning

To answer the question: “Where need to be intervened?” the information of present condition of soil erosion was used: we should intervene to where the soil erosion is critical or high potential soil erosion (table 2). Where the high intervention and has bad land cover change (vegetation loss) should be the site need to be intervene as soon as possible – the answer of question “When need to be intervened”. Table 3 describes the “when” in priority level. Base the on present condition of land cover, the intervention method can be found to increase the vegetation cover. This is answer of the last question: “What need to be done?”

Table 2. Present condition of soil erosion [4]

Soil erosion level	Annual potential soil erosion (t/ha.year)	Annual soil erosion (t/ha.năm)
No erosion	<100	<5
Weak	100-300	5-20
Marginal	300-500	20-50
Medium	500-700	50-100
Strong	700-1000	100-150
Very strong	1000-1500	150-200
Critical	>1500	>200

Table 3. Priority of intervention needed

Change of C factor (times)	Soil erosion level					
	Present soil erosion			Potential soil erosion		
	critical	strong to very strong	other	critical	strong to very strong	other
>2	high	medium	medium	high	medium	low
1-2	medium	medium	low	medium	medium	low
<1	low	low	low	low	low	low

4. Result and Discussion

The map of land cover change and map of soil erosion change then are overlaid and analyzed. The main idea of analysis is how much the vegetation cover should be change in order to remove the critical soil erosion in the watershed. When the vegetation cover change (in future) has been recognized, the intervention method is specified based on the certain condition of the site (topography, assessment level, present vegetation cover). It was shown on a map, i.e. the question where is answered. Depends on the present land cover situation as well as rapid of change linked with the soil erosion change, the area when the intervention needed to be done is separated.

Combination these information, the land use planning map of the Tra Khuc watershed was created as shown in figure 5. Table 4 is area of each type of intervention and priority in the Tra Khuc watershed has planned.

In the watershed, the total area of protection is 88%. The high priority is in the West of the watershed where the potential soil erosion is high and the vegetation cover is loosing.

The study shows the effect of the land cover change to soil erosion is directly and can be quantified for land use planning by GIS. It makes the building an information system for land use planning decision possible with GIS as a nuclear and remote sensing system as an input data system.

Mapping approach however, will bring the information needed to the land managers to help them in the decision process. The model used in this paper based on the natural conditions only (on-site information) but not included the off-site information [1]. It may need another (or further) model to combine the on-site and off-site information to make the land use plan becomes more reality and useful in term of soil erosion control in broad scale.

Table 4. Intervention area

Intervention and priority		*Area (ha)*	*Area (%)*
Intervention	*Priority*		
Reforestation	High	48.51	0.014
Agro-forestry	High	2766.24	0.816
Natural re-growing conservation	Medium	8673.39	2.557
Protection	High	59743.98	17.614
Protection	Medium	226328.04	66.729
Protection	Low	11896.38	3.507
No intervention	Low	29718.63	8.762

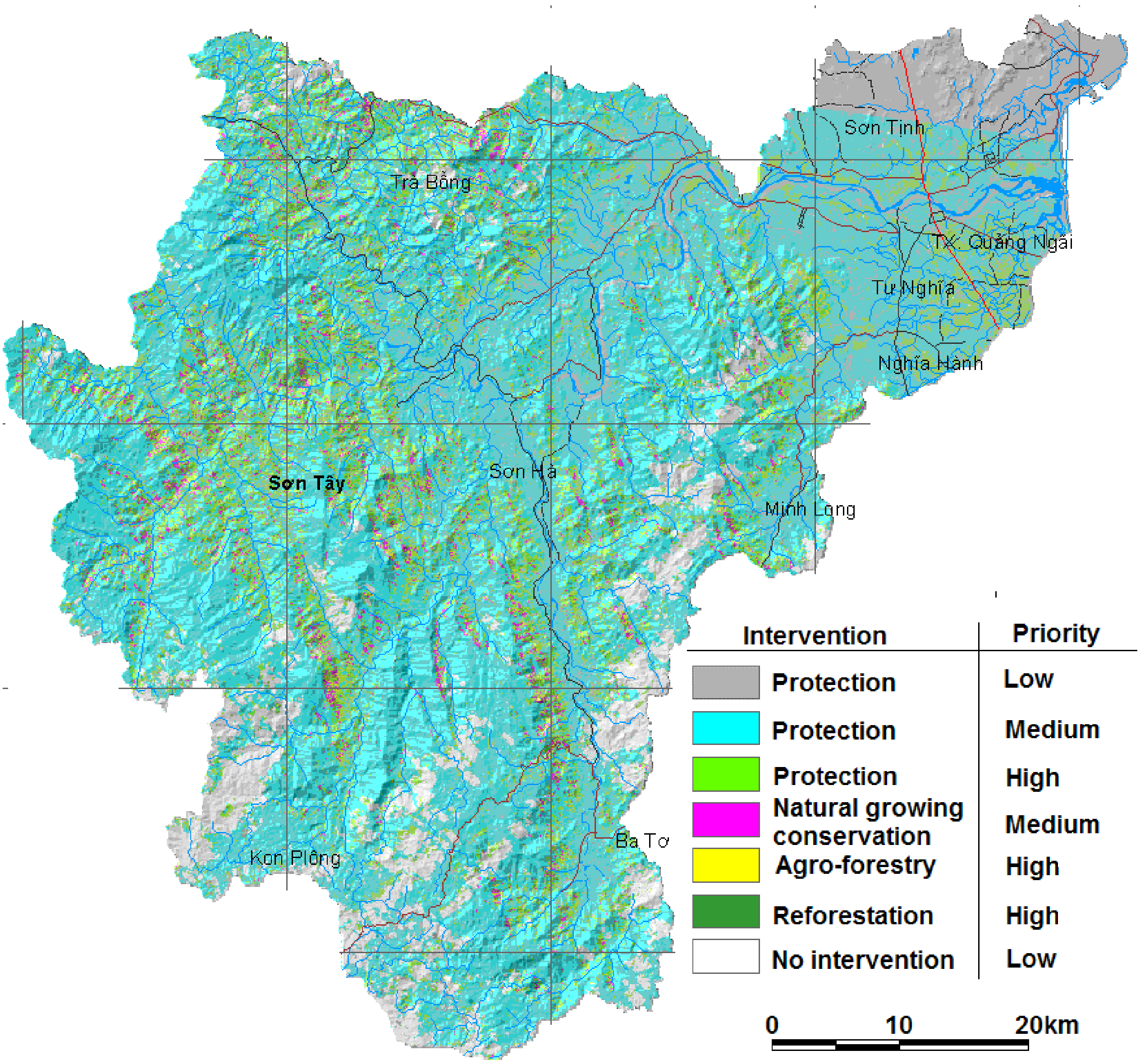

Figure 5. LUP map of Tra Khuc watershed

5. Conclusions and Recommendations

The analysis of effect of land cover change to soil erosion has been done spatially by application of GIS. It makes the advantages in time and cost for calculation in broad scale. The land use planning built on these information is quite quantitative, but a good plan can only be done through a combination of regional policies and sensitive local management.

The USLE approach specifically does not address off-site issues; it has no reference to redistribution within the landscape or to export into the hydrological network. To the land use planning purpose, the off-site issues can be considered also the scosio-economic conditions of the watershed. The suggestion has been made that sediment budgeting, partitioning according to process, and spatially distributed routing of sediment all need to be undertaken in soil loss model. In particular, spatial and temporal controls on erosion and sediment redistribution from sources to sinks must be incorporated into modeling, with specific recognition given to the dynamic nature of sediment delivery. Linked to the scosio-economic conditions, it may require another model that counts these conditions in the planning process.

Countries really need some means of using existing data to obtain national scale indices of both on-site and off-site erosion problems. The suggestion is that there is a need for a simple tool, equivalent to the USLE approach, to model off-site consequences of erosion, i.e. to identify the sources of sediments that cause off-site effects.

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