A RESEARCH ON EROSION AND COUNTER-MEASURE OF SOIL EROSION BY WATER USING GIS TECHNOLOGY

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ABSTRACT

Soil erosion is one of reasons to make the nutriment of soil become poor and poor. The article points out the causes of soil erosion and how to apply the GIS technology to evaluate the soil erosion by water in Tam Nong district, Phu Tho province, as well as providing the methods to prevent it for protecting sloping land.

1. INTRODUCTION

Soil erosion was indentified as one of the major reasons of soil degradation. It is nessessary to monitor and assess the state of soil erosion and propose counter measures for the land resource utilization, protection and management. Soil erosion assessment is the initial step for sustainable agriculture activities. Base on intensity, temporal density and spatial scale, soil erosion is evaluated, classified and mapped to support for erosion assessment, erosion hazard mitigation, and land resource preservation.

Geographical information system (GIS) has been use as effective storage, management, analyst, and support tool for natural resource management. It had been applied successfully on researches in the field of agriculture, such as soil analyses, soil erosion assessment.

In this study, a procedure for establishing soil erosion map was prososed to be a fundamental for widely applying in different regions, in different research fields, such as land use planning, sustainable agriculture development. The cultivation methods to reduce soil erosion and preserve the soil fertilization are expected to be proposed from the result of this research.

GIS application combined with soil erosion prediction model and computing and simulating tools in Vertical Mapper software had been used to overlay and establish erosion maps in which each mapping unit equivalent to a 10m x 10m pixel. Base on those results, intensity and location of soil erosion areas will be identified which helps local government designs plans for soil protection and land sustainable development.

2. SOIL EROSION CAUSED BY WATER

Erosion by water is common phenomenon on the Earth surface. It used to appeare in humid tropical climate zone where over flows often occur on the land surface due to by high annual precipitation, high seasonal intensity combined with steepy slope. Surface flows not only lead to a huge loss of water resource in rainy season (approximately 50% - 60% annual rainfall) but also derive land loss in many steepy regions. This causes severe damages in agriculture land, where the top soil is eroded and can not be used for cultivation. As the erosion process, small soil particles on the top soil, which occupy high nutrients, are swept away cause soil degradation.

Erosion by water often occurs in wet tropical countries, where has high rainfall. Erosion risk depends not only on raindrop impacts on soil and flow on the land surface, but also other factors such as slope, slope length, soil texture, and cultivation methods. Those accumulative impacts are estimated using universal land loss equation proposed by Weischmaier and Smith as following:

$$A=R.K.LS.C.P$$

where: R: rain and flow factor,
K: soil erosion factor,
L,S: terrain factors,
C: land cover and management factor,
P: human cultivation factor,

Impacts of above factors on soil erosion are described as following:

2.1 Rain and flow factor R

This is the factor to measure the power of erosion and surface flow, which is identified by total rainfall and rainfall intensity. Erosion level is weak if the high annual rainfall is cumulated by many light rains. Inversely, erosion is high potential in where has not high rainfall but high intensity rainfall, which used to occur in semi-drough areas.

Land loss due to erosion is also influenced by rainy season distribution. Land losses higher in areas where has heavy rains before cultivating or after havesting.

It is noticed that impacts of erosion are different between areas due to the difference in rainfall and rain intensity. To establish erosion by water map, it is nessessary to create average rainfall map of the research areas.

2.2 Soil erosion factor K

Soil erosion factor – K is the level of soil erosion. The natural land loss is estimated in pilot area which has 22m length and 9% slope equivalent to 16o in continuous uncultivated condition. Infiltration and the stability of soil texture are two major components affect on soil erosion factor. The soil infiltration ability is mainly influenced by the stability of soil texture – especially on top soil, soil components, and soil nutrients. The stand of soil from the rain impact in tropical zone can be strengthen by the stabilities of iron hydroxit and aluminum hydroxit particles.

Erosion factor K is identify in the range from 0 to 0.6. It has small value in areas where have soft soil texture, high permeability and fast drain water or soil types in tropical zone where has iron, aluminum or kaolinit minerals. The soil which has moderate permeability and moderate texture stability used to has K in the range from 0.2 to 0.3. K is greater than 0.3 in which has high erosion potential and low permeability.

In this research, soil maps and ArcGIS software were used to establish K factor maps.

2.3 Terrain factors L,S

The topographic factors, slope length and slope, are identified as L, S in the mentioned equation. Except other factors, the higher slope is, the higher erosion possibility will occur because of high flow velocity. In theory, when flow velocity increases by twice, the movements of soil particles can be 64 times faster, dissolve materials in the water increase 30 times those result in soil erosion will be 4 times higher.

Slope length is also an important factor for the erosion process because the slope area will be larger which cumulates high water flow on the surface. For example in south West Lowa, water flow increased 1.8 times when slope of 9% was increased by twice, those

resulted in the 2.6 times increase of land loss. Therefore, control drainages used to be designed across the slope to reduce the land loss.

Soil erosion has higher potential where the slope is high,

To establish soil erosion by water maps, maps of L and S factors were created from topographic maps of research area using ArcGIS software.

2.4 Land cover and management factor C

This factor identifies the impact of vegetation cover and land use, land management method on land loss by erosion. Forest tree and grassland are the best nature land protection. Besides, crop plants which have high density cover such as cereals, legumes, etc also can against erosion.

The erosion can be reduce effectively by the combination between annual cultivated crops and the land cover preservation with a suitable rotation system so called "soil protection cultivation system". Soil erosion can be lessened if the remnant vegetation is preserved by applying this cultivation system.

The C value for different areas depends on many factors include existing land cover, plant growth period, cultivation method, and other land management factors. C value is high (reach to 1.0) in low density land cover areas such as newly furrowed land, newly sowed or cultivated land where canopy has not grown yet. Inversely, C value is lower (< 0.1) in areas where have high density forest cover or large remnant plants. Land cover density plays an important role in reducing the splash of raindrops on soil particles and velocity of surface flow. It is required to derive C factor map from land cover maps for the establishment of erosion by water map.

2.5 Human cultivation factor P

This factor shows the impact of cultivation on soil erosion process such as plantation along the contour line, range plantation, terraced cultivation and drainage networks, etc.

The uncontroled forest exploitation, forest fire for cultivation, and then ploughing are damaged activities on the slope. Especially, this cultivation method use to be carried out before rainy season makes soil eroded easily since the early rains. Unsuitable cultivation method on slope such as cultivation along slope direction, the lack of range of protection plant to control the flows are the reasons strengthening the soil erosion.

P is indentified according to the scale of land loss occurs in parcel which applying against erosion measures in compare with parcel which does not apply erosion controling method. For example, P = 1 where has no erosion control activities. P values are listed in the following table in the case plants are cultivated along contour line or in range in different slopes.

Table 1. P values for terraced cultivation along the contour line and in range

Slope (%)	Contour line cultivation	Range cultivation
1-2	0.6	0.30
3-8	0.5	0.25
9-12	0.6	0.30
13-16	0.7	0.35
17-20	0.8	0.40
21-25	0.9	0.45

The effective methods to control the impact of flow and reduce soil erosion process are

contour line plantation and range plantation in combination with protection range arranged along contour line, increase of plant density or creating of buffer of protection land.

Table 2. Impact of land management on surface flow and soil erosion on 8% slope

Land management	Average overflow (%)	Average annual land loss (ton/ha/year)
Uncultivated land	29	143
Planting cotton consecutively, cleaning farming	10	49
Crop rotation	9	-
Grass cover	> 1	-
Annual fired forest	3.5	0.1
Non fired forest	< 0.3	-

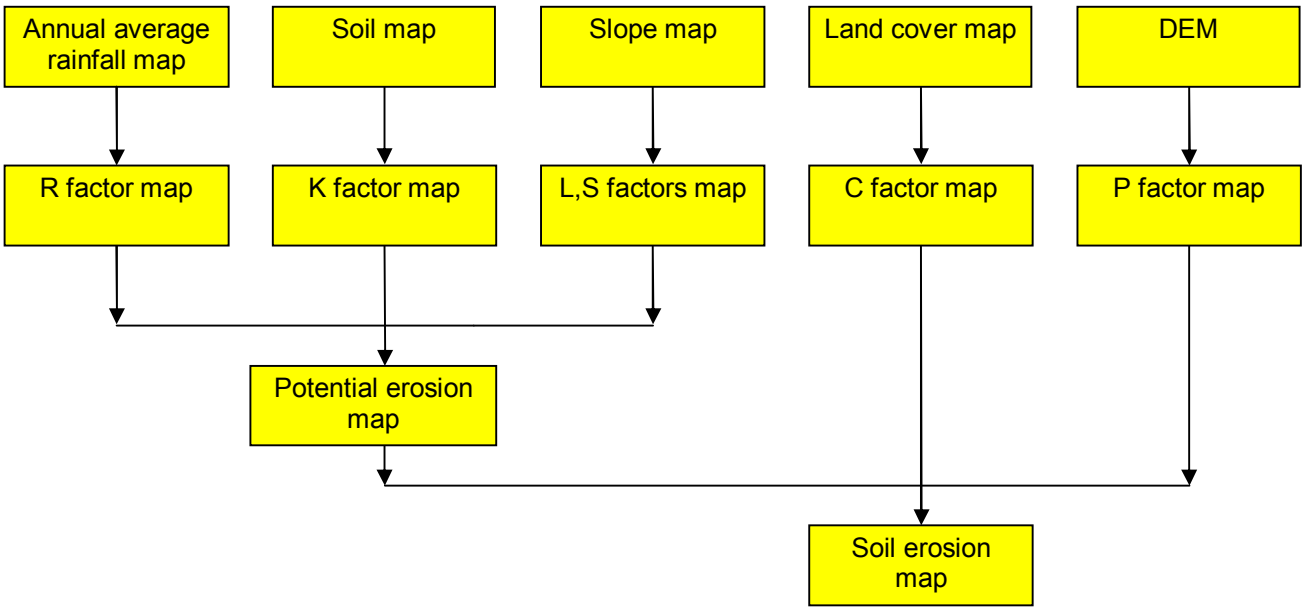
Base on slope map of the research area, P factor was mapped for the further soil erosion research steps using ArcGIS software.

3. APPLICATION OF GIS TECHNOLOGY FOR SOIL EROSION MAPPING

Component maps were overlaid to assess and map soil erosion using GIS technology

- R coefficient map was mapped from annual average rainfall maps.
- K coefficient map was created from soil maps
- L and S coefficient map were derived from topographic maps.
- C coefficient map was established from land cover maps.
- P coefficient map was generated from slope maps

Soil erosion mapping using GIS technology was applied using the following overlay model:



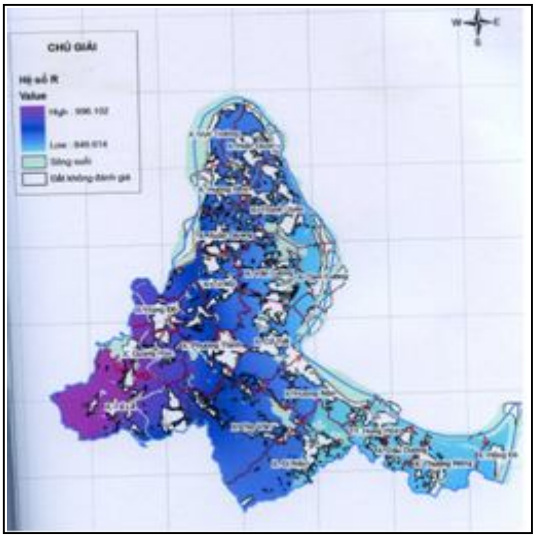


Figure1. R factor of TamNong map

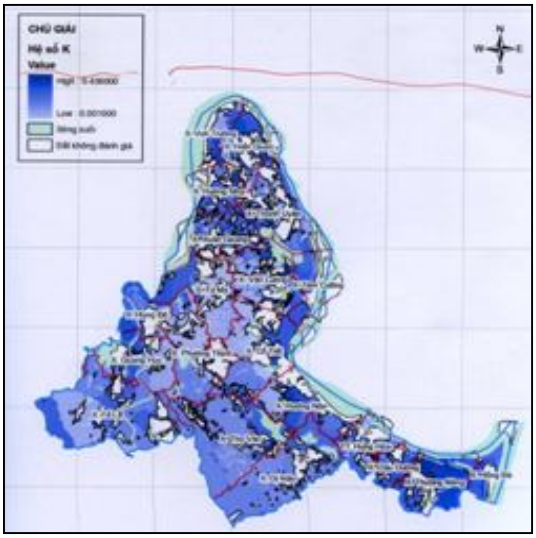


Figure 2. K factor of TamNong map

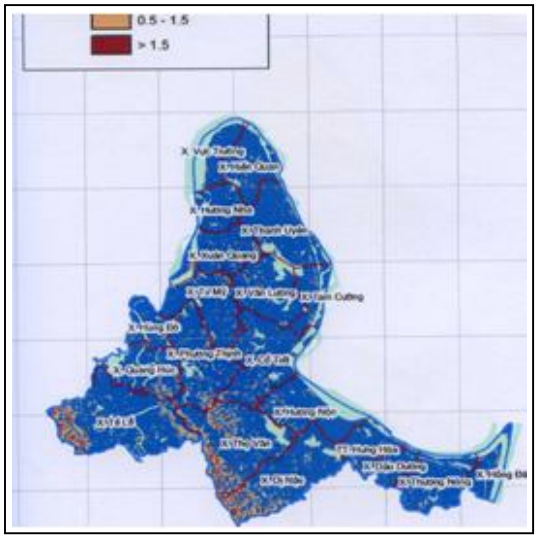


Figure 3. L,S factors of TamNong map

Figure 4. K factor of TamNong map

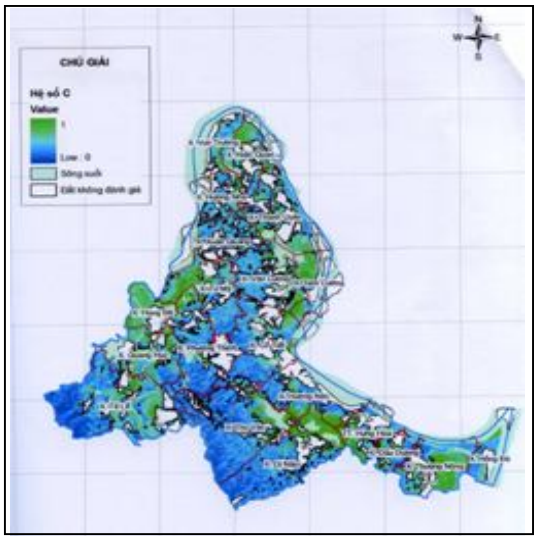


Figure 5. P factor of TamNong map

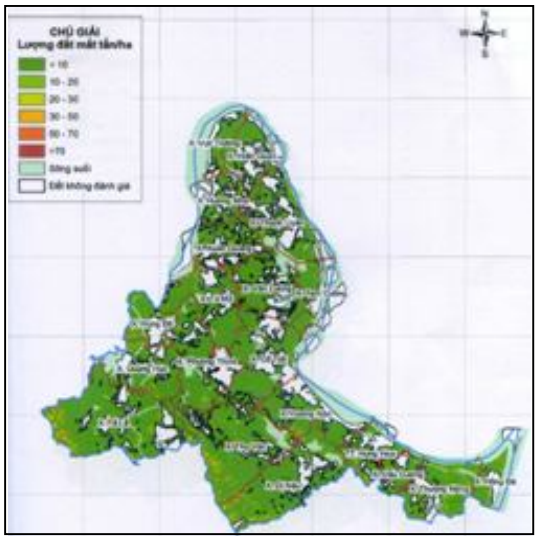


Figure 6. Soil erosion of TamNong map

4. MEASURES AGAINST SOIL EROSION BY WATER

Some measures to control and reduce soil erosion were pointed out as following base the results of this research.

- Terraced farming, planting in range and along the contour lines to reduce the length L and steepness S of the slope.
- Drainage network is need to be contructed along contour line to reduce the water flow on the surface and shorten the local slope length.
- Planting of trees which have well developed root systems. Vegetation cover needs to be remained after harvesting to reduce soil erosion by water.
- Plantation with suitable density.
- Suitable rotation cultivating systems needs to be developed to against soil erosion and improve the fertility of the soil.
- Information disseminating and training for local people to recognize the damages of soil erosion and counter measures.

5. CONCLUSIONS

- This study has successfully proved the necessary requirement, feasibility of applying GIS technology for soil erosion by water mapping.
- Base on the research results, the suitable counter measures to control and reduce erosion in Vietnam have been proposed applying the advance science and technology.

6. REFERENCES

Nguyễn Trọng Hà (1996), *Xác định các yếu tố gây xói mòn và khả năng dự báo xói mòn trên đất dốc*, Luận án tiến sĩ kỹ thuật trường Đại học Thủy Lợi, Hà Nội.

Nguyễn Quang Mỹ (2005), *Xói mòn đất hiện đại và các biện pháp phòng chống*, Nhà xuất bản Đại học Quốc Gia Hà Nội, Hà Nội.

Trần Quốc Vinh (2010), *Xây dựng cơ sở dữ liệu đánh giá xói mòn đất bằng công nghệ viễn thám và GIS phục vụ công tác bảo vệ đất dốc huyện Tam nông tỉnh Phú Thọ,* Đề tài cấp Bộ, mã số B2008-11-102.

Bennett H.H (1993), *Soil Conservation*, Graw-Hill, New York and London.

Govers G. (1991), *Rill erosion on arable land in central Belgium: rates, controls and predictability*, Catena, 18: pp133-155.