

USE OF EROSION HAZARD ASSESSMENTS FOR REGIONAL SCALE CROP SUITABILITY MAPPING IN THE UVA PROVINCE

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ABSTRACT

The Uva Province is the largest province in the country and it is highly vulnerable for land degradation, particularly the soil erosion. Prudent use of land resources in these areas are the key to ensure long-term productive capability & sustainability of such resources. Therefore, a research study was conducted to identify land related limitations and potentials within Uva Province in the view of identifying suitable land management and land use options. Geo-spatial input data representing rainfall, soils, land slopes and land use were used to model the soil erosion hazard, which was assessed using Arc Map GIS software. In addition, field data were collected through field surveys, along with field observations. Suitable crops or cropping systems were proposed for each Agrarian Service Divisions (ASD) in order to minimize the soil erosion hazard and enhance the crop productivity. Several aspects such as crop recommendations of DOA, agro-ecological requirements, available resources in the ASD area, and social acceptance were considered in crop recommendations. The study revealed that 16 % (1,389 km²) of the land area lying in Uva Province is extremely vulnerable to soil erosion. Furthermore, it indicates that the majority (nearly 879 km² or 63 %) of such lands are situated in Badulla District. The soil erosion hazard map prepared for the province was utilized to identify suitable areas for growing perennials, annuals and to come up with a regional land use recommendation map in order to minimize soil erosion risk of the area. This approach paves the way to utilize the land as per to their suitability, and thus, ensures long-term sustainability.

KEYWORDS: Erosion hazard, GIS mapping, Land use, Uva province, Suitable crops.

INTRODUCTION

Uva is the largest Province of Sri Lanka. It consists of two administrative districts, namely, Badulla and Monaragala, which are greatly affected by soil erosion due to unsystematic cultivation, settlement in unsuitable lands, poor land management and deforestation. The Province exhibits high agro-ecological diversity and consists of 18 agro-ecological regions (Punyawardena *et al.*, 2007). Thus, there is a high degree of variability in agricultural activities and cropping patterns practicing in the province. Moreover, some parts of the province are more vulnerable to natural disasters. A common natural disaster is landslides / earth slips, particularly in the southern part of Badulla district. Studies of Bandara (2011) revealed that vulnerability to landslide in this part has been enhanced by both natural processes and by human activities such as improper cutting of earth banks, road cuts and unsuitable land use practices. This

situation would not only lead to accelerate the land degradation, but also will jeopardize the living conditions of the communities in those areas.

Thus, it is important to take necessary steps to minimize the land degradation processes through judicious utilization of land resources. Implementation of a land use plan, which is prepared through a careful study of land related limitations and potentials will be the best regional scale mitigatory measure to minimize the threat of land degradation, particularly the soil erosion. In this context, soil erosion hazard map prepared for a given area will be a very effective planning tool to compile a scientifically based land use recommendation plan along with a proposal for suitable crops / cropping systems and related land management options. Hence, this study was carried out with an overall objective of preparing a soil erosion hazard map for Uva Province to utilize the same as a planning tool to decide crops and cropping systems to finalize a map for the province depicting land use recommendations, in the providence order to implement a suitable land resource management approach in regional level.

MATERIALS AND METHODS

The study was conducted in Badulla and Monaragala Districts of the Uva Province. Information was gathered through available literature, existing maps depicting topography, land uses and agro-ecological zones and through informal interviews & focused group discussions. The study was carried out in two steps. The step one was concentrated to assess the soil erosion hazard under present land use. Subsequently, the output of the step one along with other input data such as agro-ecology and elevation data to represent temperature regime were used in the second step to identify suitable crops / cropping systems.

Preparation of soil erosion potential map for Uva Province

Although there are many models for estimation of soil erosion potential in larger areas, Morgan (1995) has identified the most common basis for such modelling approaches is the use of input parameters in the Universal Soil Loss Equation (USLE) for smaller areas such as hill slopes and fields. The inherent soil erosion potential of a particular area depends on rainfall, soils and terrain characteristics which can be represented by input data such as erosivity of Rainfall (R), erodibility of Soil (K), Length of slope & percentage of slope or Slope coefficient (LS) factor, respectively. Integrating the effects of existing land cover (C) and their management practices (P) along with the soil erosion potential, results the soil erosion hazard for the area (Morgan, 1995). Influence of the slope length factor (L) was not considered in similar studies

(Munasinghe *et al.*, 2001) as this is a highly localized input, which may not make a considerable impact on a regional scale study of this nature.

The Digital Elevation Model (DEM) for the Uva Province was prepared by using 20m digital contour maps of the Survey Department. The DEM was used to generate slope map for the study area. Rainfall erosivity map compiled by Wickramasinghe and Premalal (1988) was improved with available additional data points and was considered as the base map for rainfall erosivity. The erodibility values for soils found in the Uva Province were gathered from available literature of previous studies (Bandara 1991; Zijlstra 1989). Soil erosion potential map was prepared by using three input databases, erosivity of rainfall (R), soil erodibility (K) and slope percentage (S), which were in the same geographic coordinates. The above input spatial data were converted into Grid databases with 250m resolution, as the particular grid size is not only convenient for spatial analysis, but also capable enough to represent the spatial variability more realistically.

Arc Map GIS 10.1 software was utilized to overlay the above three grid databases to generate an intermediate output which represents the relative potentials of soil erosion. The above intermediate output was then reclassified to show five qualitative classes of potential soil erosion hazard, namely low, moderate, high, very high and extremely high using natural breaks method in classification tool of Arc Map GIS software at previous studies (Munasinghe *et al.*, 2001).

Preparation of Soil erosion hazard map

Soil erosion potential map was taken as an input data to generate soil erosion hazard map for the Uva Province. Land cover factor (C) and management practices (P) also play a role in soil erosion hazard. However, management practices are highly localized and vary at individual farm level. Therefore, its effects are scattered and will not be represented in this regional scale studies. Thus, only land cover factor was taken into consideration. The land use maps of 2012 for each district were obtained from Land Use Policy Planning Division of the District Secretariats in Uva Province and used to identify the new land use pattern in each district. The C factor was generated for existing land uses in the Province by using the same approach used in similar studies (Munasinghe *et al.*, 2001).

Arc Map GIS 10.1 software was utilized for spatial analysis to assess the soil erosion hazard. Soil erosion potential map was considered as the base map. A layer map was produced by using C-factor and overlaid in to the base map in order to generate the erosion hazard map as an intermediate output. Same geographic coordinates and grid size

(250m) were used in both layers. Generated map (intermediate output) was reclassified into five soil erosion hazard classes, namely low, moderate, high, very high and extremely high by using natural breaks method in classification tool of Arc Map GIS 10.1 software.

Generated map (intermediate output) through spatial analysis were not entirely representing the actual field situations. This intermediate output was field validated through comparing the erosion risk of sample sites with that of pre-identified benchmark sites. Field observations and opinions of field officers were made at the sample sites to verify land use patterns and agricultural practices. Fragile areas mostly sensitive for natural disaster in the Province were also considered at the field observations. Corrections were accommodated into generated map to obtain the final output of soil erosion hazard map for the Uva Province.

Mapping of regional scale crop suitability for Uva Province

A field survey was carried out to collect primary data in order to assess the regional scale crop suitability in the province. The questionnaire was developed as the survey instrument to assess the cropping systems and suitable crops for Agrarian Services Divisions (ASD) in the province. Data were collected through interviews with relevant agriculture officers. One interview for each ASD was held and information was collected for 49 ASD's in the province. Qualitative analysis was used and results were interpreted in descriptive manner to identify the most suitable crops for each ASD area as input data for the map.

Informal discussions were used as data triangulation instrument to consolidate the data of field survey. Ten informal discussions were carried out with government officials, private sector and farmers in both Badulla and Monaragala districts. Agro-ecological map of Uva Province was used as the base map. Suitable crops for ASDs were identified separately and used as an input data layer to generate crop suitability map. Agro-climatic requirements of each crop were demarcated separately as another input data layer. Two input data layers were overlaid and intercepted areas were delineated to generate the potential growing areas (intermediate outputs) for each crop using Arc Map GIS spatial analysis capabilities.

Group discussions were made with respective agricultural officers in the province for initial validation of generated maps. Environmental issues, land use practices, farming issues, and potential and projected disaster vulnerable areas were also considered. Necessary corrections were accommodated and it was further validated by using crop recommendations of the Department of Agriculture and experts' knowledge.

Table 1. K values for major soil types in Uva Province.

Soil Type	K Factor value
Reddish-Brown Latasolic	0.17
Sandy Regosol	0.48
Reddish-Brown Earth	0.27
Red-Yellow Latasol	0.33
Non-calsic Brown	0.35

The slope percentage map layer was derived from Digital elevation model which can be classified to five erosion potential categories. The distribution and extents of five erosion potential categories in Uva Province are given in Figure 2 and Table 2, respectively.

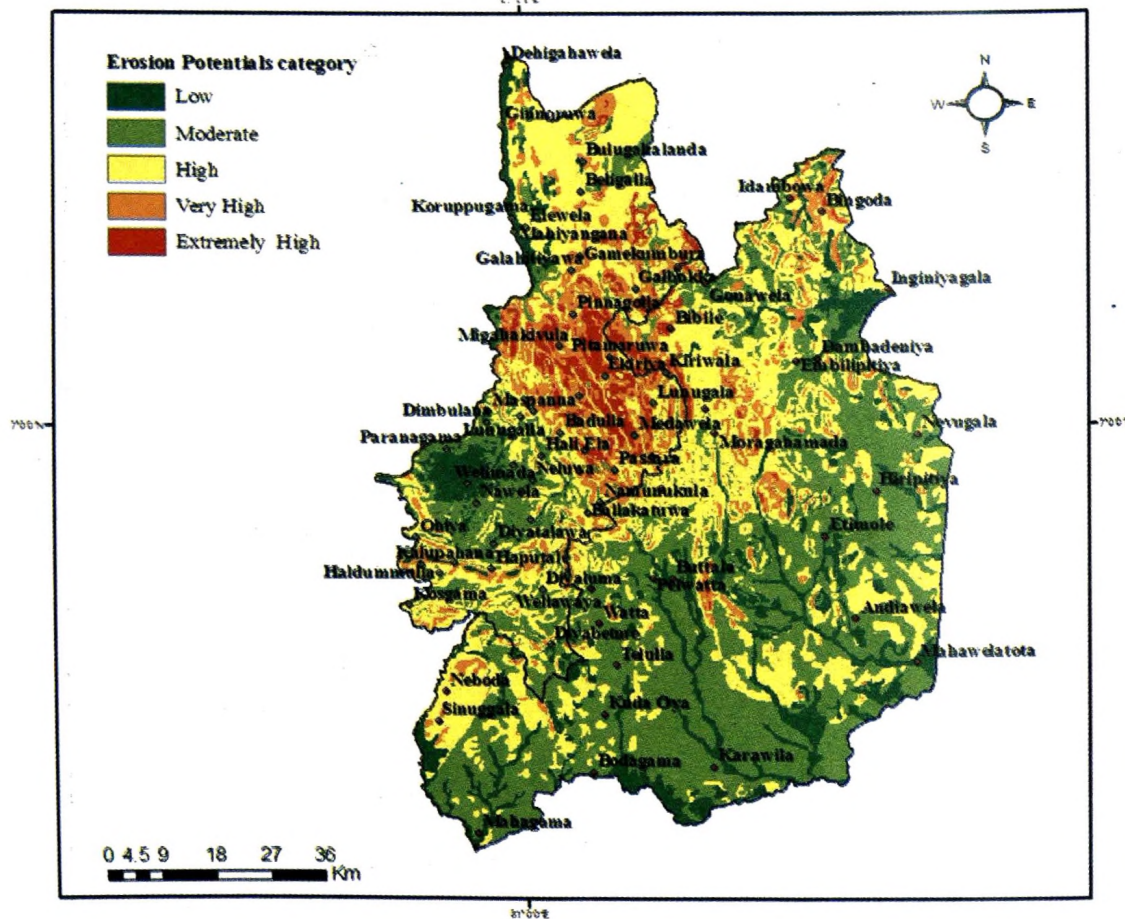


Figure 2. Soil erosion potential map of Uva Province.

Soil erosion potential map reveals that 68 % of the land area in Badulla district is fallen in between high to extremely high erosion potential categories. This area predominantly consists of Red Yellow Podzolic soils and Mountain Regosols and exhibit mountainous, steeply dissected, hilly and rolling terrain. In addition, this area is

experiencing very high erosive rains compared to other areas of the province. Therefore, the combined effect of all the factors are affecting the area and thus, highly vulnerable to soil erosion.

Table 2. Extent under each erosion potential categories for each district and Uva Province.

<i>Potential Erosion categories</i>	<i>Uva Province Area(sq km)</i>	<i>%</i>	<i>Badulla (sq km)</i>	<i>%</i>	<i>Monaragala (sq km)</i>	<i>%</i>
Low	1,055.85	12.3	249.54	8.8	806.31	14.1
Moderate	3,385.35	39.5	609.61	21.6	2,775.73	48.3
High	2,860.01	33.4	1,140.19	39.8	1,719.82	29.9
Very High	1,012.19	11.8	633.21	22.3	378.98	6.8
Extremely High	256.83	3.0	207.95	7.5	44.12	0.9
Total	8,570.22		2,840.50		5,724.96	

In contrast, only 37 % of the total land area of the Monaragala district is fallen into high, very high and extremely high erosion potential categories. The Monaragala district receives comparatively low erosive rains and exhibits moderate terrain characteristics compared to Badulla district. Although most of the areas in the district consist of Reddish Brown Earth (RBE) soils which possess high erodibility compared to Red Yellow Podzolic soils, the spread of RBE on an undulated terrain with mild steepness results in less soil erosion potential. In contrast, areas where there are higher slopes and/or areas having Non Calcic Brown soils exhibit high erosion potential. In North-eastern tip of Monaragala, district such as Neliyadda ASD division, northern part of the Senanayake Samudraya exhibit a higher erosion potential and it is due to the existence of already eroded remnants (Inselberg) or Non Calcic Brown soils or higher slopes.

Soil erosion hazard

The soil erosion hazard map indicates the effect of present land uses on soil erosion potential in the province. The C factor layer was derived based on the existing land use map of 2012. The C factor values for each land use are given in Table 3. The soil erosion hazard map and categories in each district are shown in Figure 3 and Table 4, respectively. Soil erosion hazard map for the Uva Province shows that the threat of soil erosion is much higher in Badulla district under the existing land use scenario. The percentage of land area falling into extremely high erosion hazard category in Badulla district is higher than the Monaragala district. Badulla, Haliela, Haputhale, Passara, Madawela, Pinnagolla areas are falling into extremely high category, which is around 30

% of the total land area in the Badulla district. Major soil types of these areas are Red-Yellow Podzolic soils and Mountain Regosols, while the terrain is ranging from mountainous, steeply dissected, hilly and to rolling, which are vulnerable to soil erosion. Very high erosive rains are normally experienced in northern part of the province and steepness is also more than 60 % at these areas.

Table 3. Land uses and related C factors.

<i>Land Use Type</i>	<i>C factor</i>	<i>Land Use Type</i>	<i>C factor</i>
Annual crop	0.80	Marshy lands	0.30
Banana	0.73	Open forest	0.50
Built up areas	0.73	Other crop lands	0.73
Cannel	0.40	Paddy	0.43
Chena	0.80	Play ground	0.80
Coconut	0.54	River	0.50
Dense forest	0.20	Road	0.70
Forest plantation	0.45	Rock	0.10
Grass lands	0.51	Rubber	0.44
Homegarden	0.51	Scrubs	0.60
Mango	0.44	Streams	0.20
Tea	0.57	Tank	0.20
Sugarcane	0.73		

Table 4. Extents under soil erosion hazard categories in each district and Uva Province.

<i>Category</i>	<i>Uva Province Area(sq km)</i>	<i>%</i>	<i>Badulla (sq km)</i>	<i>%</i>	<i>Monaragala (sq km)</i>	<i>%</i>
Low	343.01	4.0	22.40	0.79	319.82	5.6
Moderate	2,055.79	24.0	248.29	8.74	1,806.60	31.6
High	2,933.04	34.2	898.94	31.65	2,032.23	35.5
Very High	1,849.16	21.6	790.59	27.84	1,057.35	18.5
Extremely High	1,389.22	16.2	879.83	30.98	508.95	8.8
Total	8,570.22		2,840.05		5,724.96	

In terms of land use, most of these areas are covered by homegarden, tea, paddy, forest and shrub lands. With recent urbanization trends, the urban settlement expansions have been increased and thus, agricultural activities have moved from suitable land areas to unsuitable steeply hilly areas. Most common agriculture practices are tea and vegetable farming (annual cropping with more soil disturbances) with less soil conservation measures causing higher degree of erosion hazards in these areas. In addition, some of the tea lands are deteriorating in terms of their productivity and have become marginal tea lands over the years and these could be the other reasons for highest

combined effect of forest cover, protected wildlife areas coupled with moderate terrain conditions.

Use of soil erosion hazard map for regional scale crop suitability assessments in the Uva Province

Soil erosion risk or the hazard can be altered by changing the land use of a particular area. This would be the most cost effective, long lasting conservation approach, which can be implemented at regional scale. Land areas falling into extremely high and very high categories were allocated for perennial systems in order to minimize soil erosion risks. Agro-ecological conditions, crop recommendations of DOA and other relevant recommendations of the plantation sector were considered to decide what perennial systems are suitable for respective areas. Areas suitable for tea, rubber, horticultural crops, and export plantation crops were identified and depicted in Figures 4, 5, 6 and 7 Existing distributions of different perennial systems and crops were spatially interpreted and used as a supporting proxy data for making decisions regarding crops suitability. Thus, the output will be more practically feasible and socially acceptable. Potential areas for suitable crops are summarized in Table 5.

Table 5. Potential crop categories and suitable crops for Agrarian Service Divisions of Uva Province.

<i>Crop Category</i>	<i>Suitable Crops</i>	<i>Potential Agrarian Service Divisions</i>
Plantation Crops	Tea Rubber Coconut	Kandeketiya, Hali ela, Goradiyawaka Deyaluma, Passara, Dambagalla Megahakivula, Ethimale, Kataragama
Fruit Crops	Avocado, Rambutan, Passion Fruits, Banana, Mango, Lime, Pineapple, Sweet orange	Kandeketiya, Passara, Uva paranagama Dambavenna, Megahakivula, Passara Sapugolla, Passara, Bibila, Medagama Mahiyangene, Nagadeepa, Redimaliyadda Wiyaluwa, Rideepana, Passara, Kotagama, Neliyadda Balaketuwa, Kubalwela, Redimaliyadda, Nagadeepa
Vegetable Crops	Up Country Low Country	Goradiyawaka, Lunugala, Keppetipola Maspanne, Madolsima, Kataragama Mahiyangene, Nagadeepa
Other Field Crops	Maize, Cowpea, Chili, Groundnut, Mung bean, Kollu,	Redimaliyadda, Nagadeepa Wiyaluwa, Rideepana Madolsima, Lunugala
Export Agriculture Crops	Pepper, Cinnamon, Cardamom, Cocoa, Coffee	Kandeketiya, Megahakivula, Dambagalla Higorukaduwa, Badalkumbura, Madolsima, Lunugala, Bibila, Medagama, Kotagama, Neliyadkda, Passara, Ambagasdowa .Kotawera

Since there are so many different agro ecological zones in the Province, there is a vast potential for crop diversification within the province. Matching of fruit crop requirements with available ecological environments reveals that variety of fruit crops such as avocado, banana, mango, lime, pineapple, rambutan, passion fruits, sweet orange etc. are the most potential fruit crops suitable for growing in Low Country and Mid Country Intermediate zones of Badulla district, while banana, mango, lime, pineapple, and sweet orange are the major fruit crops suitable for Monaragela district (Figure 4).

Low country area lying in Monaragala district dominantly consists of RBE soils and in terms of soil reaction, depth, texture and drainage, it is quite possible to grow wide range of crops such as cereals, pulses, oil crops, vegetables, fruit crops etc. therein. Moreover, other field crops such as maize, cowpea, chilli, groundnut, mungbean etc. are more concentrated towards dry zone and intermediate zone (Figure 7). Low temperature in mid and higher altitudes of the intermediate zone favours tea plantations, temperate vegetable cultivation and cut flower industry. Areas such as Bandarawela, Haputhale and their surrounds, which are associated with such low temperature and also the portion that exhibit higher slopes can be used to cultivate perennial crops such as tea (Figure 5). Existing tea plantations are considered to be remained without converting into other uses.

Land areas falling within the intermediate zone and exhibiting higher slopes can be utilized effectively for cultivation of Rubber and in addition, can minimize the risk of erosion in such lands. Expansion of Sugarcane cultivation is a need in the country and identification of suitable growing environments is required. The higher diurnal temperature regime of the eastern part of the Low country Intermediate zone favours cultivation of sugarcane and such areas are depicted in Figure 5 in Badulla and Monaragala districts. Areas falling in Intermediate Up country, such as Welimada, surface soil are highly eroded due to intensive utilization of steep lands for cultivation of potato and vegetables etc. Due to high land demand of the area, it was revealed that in, the vegetable cultivation is practiced in more than 60% slope areas, which is illegal as per to existing laws. Thus such areas need foremost attention when launching soil conservation programs. Potential areas for vegetable crops in Uva Province are given in Figure 6.

Figure 5. Potential areas for plantation crops

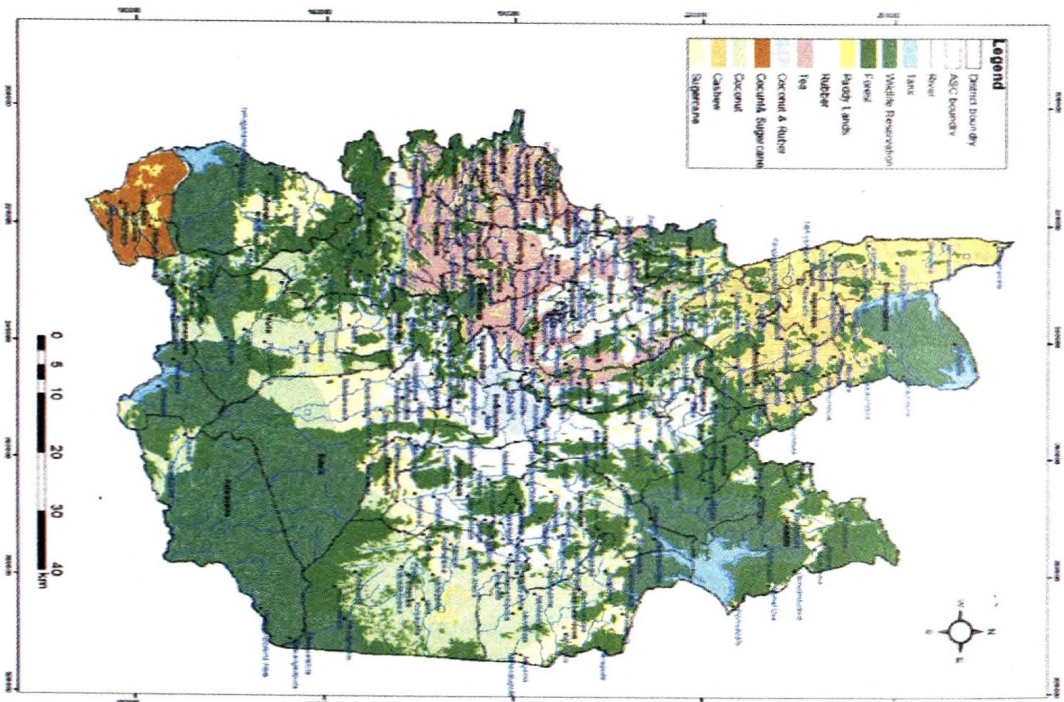
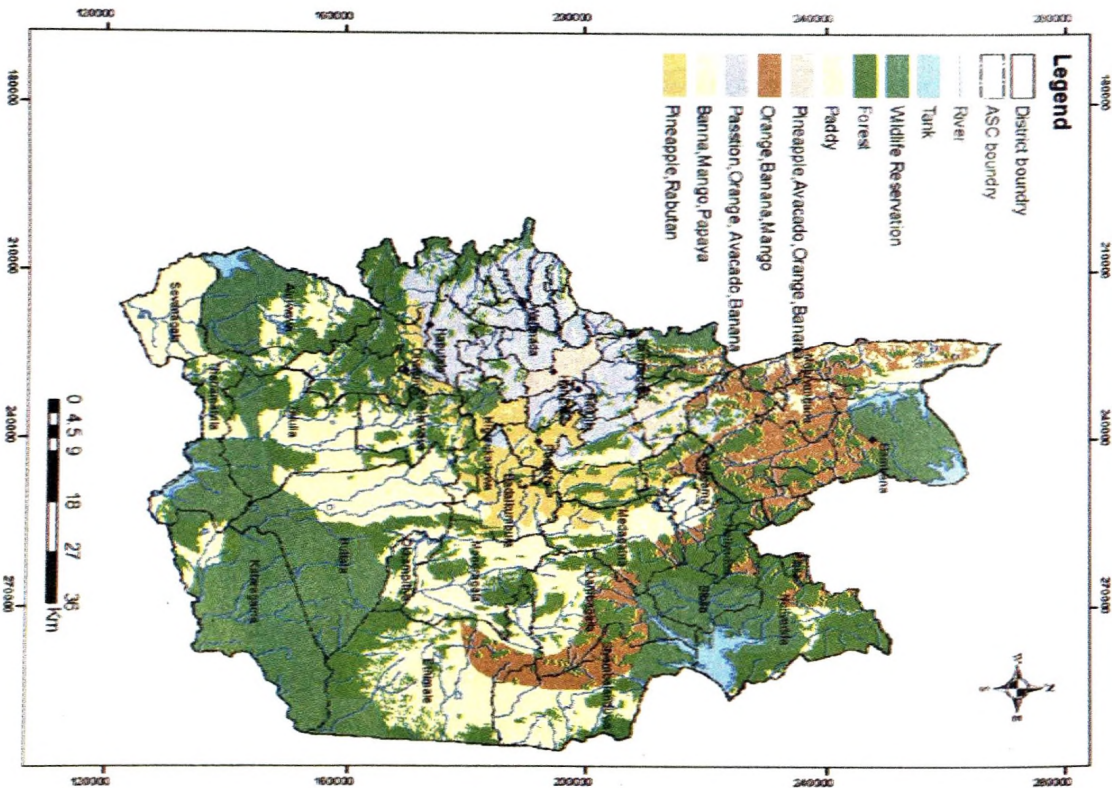


Figure 4. Potential areas for fruit crops



CONCLUSIONS AND RECOMMENDATIONS

Soil erosion hazard status of the Uva Province clearly indicates that the land degradation processors, particularly soil erosion occurring in the Province are related with improper land use practices. Nearly 37% of the total land extent of the Uva Province is subjected to high threat of soil erosion. The soil erosion hazard or the threat of soil erosion is very high in the Badulla district under the existing land use scenario compared to Moneralaga district. Crop suitability maps show potential areas for promotion and expansion of demanding crops at commercial scale. The Province is blessed with high heterogeneity in terms of crop growing environments and thus variety of crops / cropping systems are possible to be grown. In this effort, areas vulnerable to soil erosion such as lands falling into very high to extremely high soil erosion hazard classes should be cultivated with perennial systems such as tea, rubber, export agriculture crops or forestry considering the ecological suitability of the land. Annual crops / cropping systems should be restricted to lands, which are falling into lower soil erosion hazard classes along with other conservation measures. Generated map information can be effectively utilized for development planning and implementation of the Uva Province. Furthermore, these maps can be utilized to prioritize the ASD areas in the province in order to promote best land management practices along with suitable crops to minimize the effects of erosion hazards.

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