USE OF SATELLITE IMAGERY AND DIGITAL ELEVATION MODEL TO DEMARCATE DEGRADABLE LAND

Upeksha Wickramage[1], U.W.A. Vitharana[2] and Jagath Gunatilake[3]

1Postgraduate Institute of Science (PGIS),
University of Peradeniya, Peradeniya, Sri Lanka
Email:upekshawickremage@yahoo.com
2 Department of Soil Science, University of Peradeniya,
Peradeniya, Sri Lanka
Email:uvithara@yahoo.com
3Department of Geology, University of Peradeniya,
Peradeniya, Sri Lanka
Email:aajkg@yahoo.com

KEYWORDS: Landsat imagery, Agriculture, Land degradation, classification.

ABSTRACT

Land degradation due to improper land management practices in agriculture become severe problem especially in the Upper Mahaweli Catchment area (UMC). Monitoring of the ongoing land degradation requires the crucial data to identify affected areas, but they are not easy to acquire in mountainous area because of inaccessibility. Therefore this study was carried out with the objective of identify the potentially degradable areas with slope greater than 60% exploited for crop cultivation using Landsat imagery and digital contour maps. The study area was carried out Kothmale catchment which belongs to UMC, Nuwera-Elliya district. Satellite images of Landsat 8, 2013 in 30m resolution, 1:10,000 digital terrain data in 10 m counter interval, slope data and land use data collected from field survey, were major data types used for this study. Data analysis was undertaken using GIS and Remote Sensing techniques involving satellite image processing, identification of degradable slope area by generating Digital elevation model and finally estimating potentially degradable area by Boolean logic overlaying. The result reveals that nearly 17% of the total study area in the Kothmale catchment covers with degradable slope, which are particularly suitable for forest and forest plantation. By further analyzing of this degradable slope using overlaying Landuse and slope maps indicated that out of total vulnerable area 30% land is found with potentially degradable due to the agriculture. Therefore appropriate conservation and rehabilitation measures should be promoted and implemented to the areas which are being used for cultivation of tea and field crops.

1. INTRODUCTION

Global population is continuously increasing at an alarming rate in developing countries, which leads to encroachment of sloping and marginal lands in the mountainous areas for food production (Stein and Goudriaan, 2000). In Sri Lanka, like many other developing countries, the pressure on the land resources has intensified the pressure on the land resources. At present, vegetables are grown extensively on the steep slopes of the UMC without proper land management practices and these lands are exposed to severe land degradation. Land degradation is defined as the long-term loss of ecosystem function and productivity caused by disturbances from which the land cannot recover unaided (Bai et al., 2008). When considering Sri Lanka land degradation has emerged as a serious problem. According to the FAO estimates of 1989, the total extent of degraded land in Sri Lanka is about 700,000 ha, which is about 10.8% of the total arable land. (Report on Land use, 1998). Degradation of land can be resulted in many ways like heavy soil losses, high sediment yields, decline soil fertility, salinization and finally marginalization of agricultural lands. The Central Environmental Authority of Sri Lanka, which is the major body dealing with environmental issues, listed soil erosion as the major cause of soil degradation in Sri Lanka. Soil degradation refers to the temporary or permanent decline in the productive capacity of soil (FAO, 2000). Soil erosion is the combined effect of soil erodibility, intensity of rainfall, steepness of slopes and land use. Except land use all other factors are natural factors that cannot be altered by human influence. Therefore land use play and important role in protection of soil. According to the report of National Action Programme for Combating Land Degradation in Sri Lanka, it has been mentioned that nearly one-third of the land in the country is subjected to soil erosion; the proportion eroded ranging from less than 10% in some districts to over 50% in others. The most vulnerable districts are those in which high proportion of land is used for cultivation of tea, tobacco, market garden, and annual crops. But the lands with slope over 60% are generally considered unsuitable for agriculture purposes. (Ministry of Environment and Renewable Energy, 2014).

Remote sensing has long been recommended for its potential to detect, map and monitor degradation problem (Hellden and Stern, 1980; Sabins, 1987; Pickup, 1989).Thus this study attempts to identifying potentially degradable land areas having a slope greater than 60% in Kothmale Catchment by applying Remote sensing(RS) and geographical information system (GIS).

2. DESCRIPTION OF THE METHODS

2.1 Data used

The satellite imagery for this study was obtained via United State Geological Survey (USGS) Earth Explorer web site (http://earthexplorer.usgs.gov) from Landsat 8 satellite (Scene ID: LC81410552013242LGN00). This scene is Level1T standard data products which acquired day time on 30 August 2013. Image downloaded from path 141 and row55 in Worldwide Reference System-2 (WRS-2). This product has image quality score 9 and 6.64 percent cloud cover. Digital topographic maps (1:10,000, sheet numbered 61-19, 61-20, 68-24) purchased from the Survey Department of Sri Lanka having vertical intervals of 10 m was used to processed elevation data. High resolution Google Earth data and field survey data of different land use/land cover (LULC) types were used as reference data for classification process and EARDAS IMAGINE 9.2, Surfer 8, Idrisi Kilimanjaro, Google Earth Pro, R software used for this study.

2.2 Study area

The study was carried out at Kothmale catchment which belongs to Upper Mahaweli Catchment Area, Nuwera-Elliya district in lower part of Central province in Sri Lanka. It covers two Divisional Secretariat Division, Kothmale and Nuwera-Elliya. The geographic extent of the study area is 80^0 37'E to 80^0 44'E Longitude and $6^0$59'N to 7^0 05' N Latitude (Figure 1). The total area is 95.27 km^2. The climate of the area is temperate and average annual rainfall ranges from 2,000mm to above 4,500mm. The average annual temperature varies between 21^0C and 25^0C.

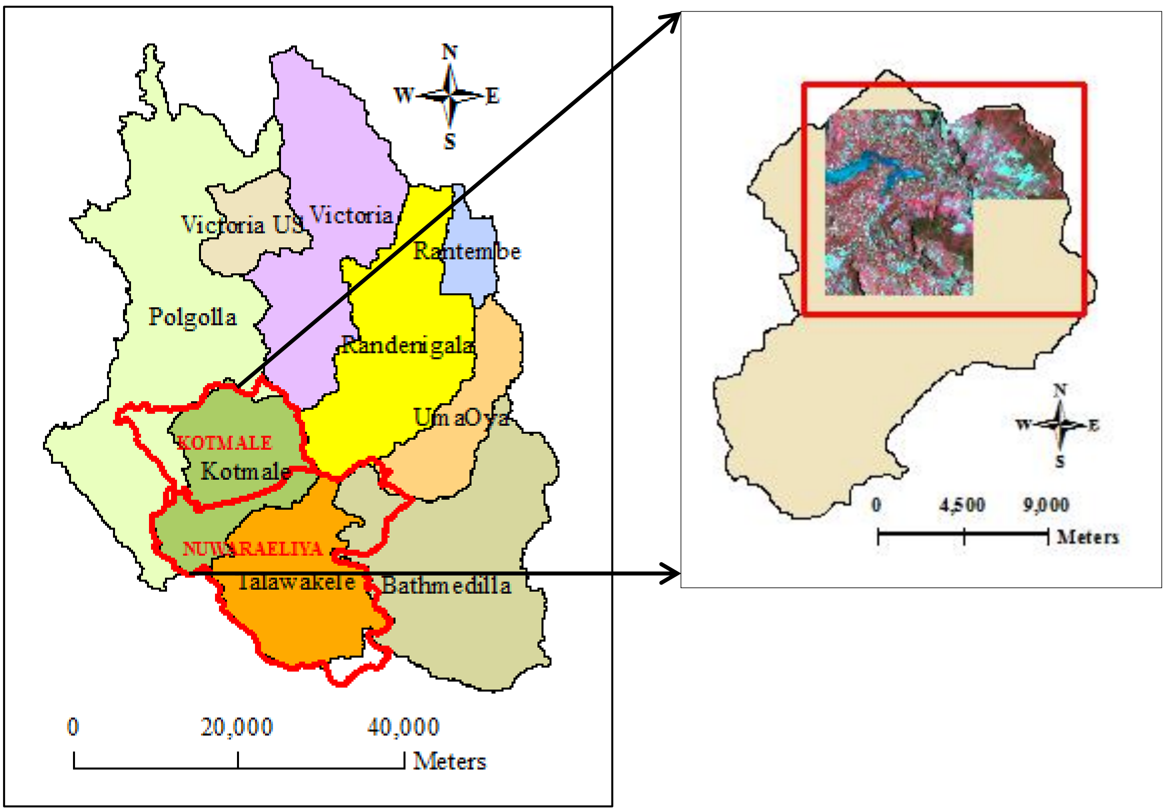

Figure 1: Localization of the study area within the Map of Kothmale

The methodological framework of this study is presented in Figure 2. The selected digital contour maps were merged together and projected into UTM_ Zone_ 44 North coordinate system which used as the common coordinate system for this study. Later merged topographic map was converted into10m*10m raster map and then into point map. After calculating X and Y coordinate of the points, DEM was generated using SURFER software version 8. Nearest Neighbor, Kriging and Inverse Distance to power interpolation methods were experimented. By analyzing these three methods visually, Kriging interpolation result which shown in Figure 3 was found to be optimal due to being sharper and less disjointed resembling the natural topography than other two methods.

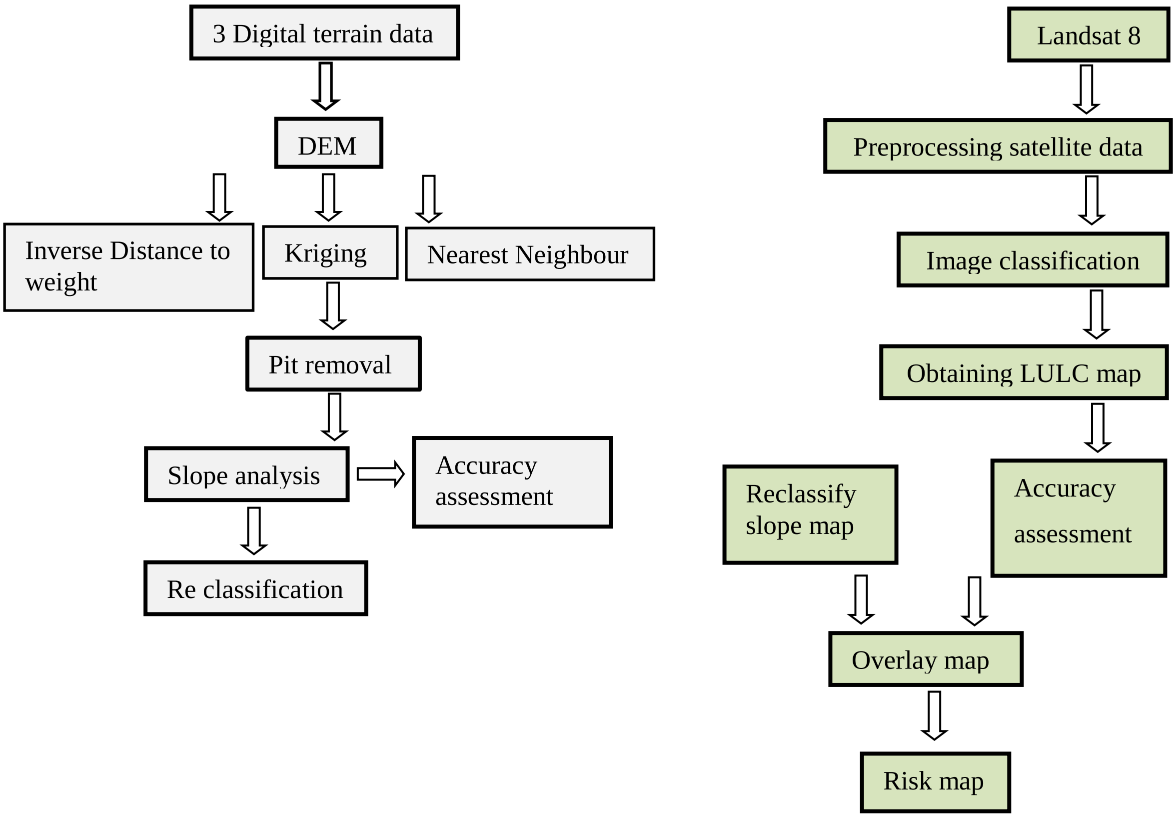

Figure 2: Methodological framework of the processing (a) elevation data and (b) satellite imagery

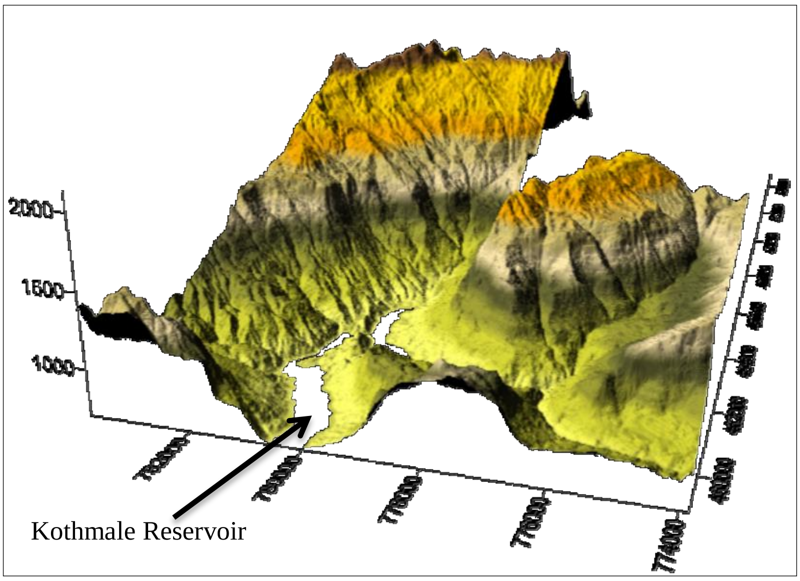

Figure 3: 3D view of digital elevation model

Then Idrisi Kilimanjaro Software used to create slope map. Created slope map was reclassified into two groups to differentiate degradable slope 60%. After producing the slope map it was checked to ensure having equivalent geographic reference (UTM_ Zone_ 44North, Datum: WGS84), pixel size and spatial extent with the classified LULC map.

Landsat 8 satellite image imported to img format in ERDAS 9.2 software and layer stacked the band numbers 2,3,4,5,6,7,9 by removing ultra-blue band, panchromatic and two thermal bands. Then the satellite image was subset for covering only the study area. There after the supervised classification was performed to differentiate the degradable land uses. By using classification tool in ERDAS 9.2, signature editor was created for defining the classes. Then using AOI, the boundaries and number of pixels for each classes were added into signature editor. Finally, 7 training sets for study area was determined. After collecting AOIs, the study area was classified into 7 classes with supervised classification by using the feature space decision rule as a non- parametric rule and maximum likelihood as a parametric rule. Google Earth images were used for ground truthing different land use and cover categories. Prior to applying supervised classification, unsupervised classification was performed to obtain an idea about the distribution of different LULC classes. USGS level I land cover classification was applied for the classification process.

Table 1: Details of land cover classes use for classification

Land cover classes	Descriptions
Shrub land	Plant community characterized by vegetation dominated by shrub, often also including grasses, herbs.
Home garden	Home garden, Kandyan Forest Garden, Perennial crops, Other plantation.
Paddy	Paddy
Crop field	Vegetables and other annual crops.
Forest	Dense forest, forest plantation, open forest
Tea	Plantation tea lands and Small holder tea lands with vegetative propagated and seedling tea.
Water bodies	It comprises reservoir, lakes, streams and other water bodies.

By applying overlay operation in IDRISI software, the produced two Boolean map layers (re classed slope map and LULC map) were multiplied to find the vulnerable area for degradation. Following equation was applied to find the percentage of degradable land.

$$\frac{degradable\ land\ area}{total\ land\ area\ over\ 60\%\ slope} \times 100$$

Eventually by adding the percentages of land uses under tea plantation and crop fields, total potentially degradable area was calculated. Later accuracy assessment was carried out to generate land use map and slope map to check reliability of findings.

3. RESULTS

Even though some classes have spectrally overlapped, maximum likelihood classification performs well in distinguishing degradable LULC in this study. The results revealed that out of the 7 LULC mapped from the 30 m Landsat data (Figure 4 and Table 2), crop fields with an area of 10.84 km^2 is accounting for 11.38% of the entire study area. Literature indicated most vegetable crop fields in the wet zone of Sri Lanka is under land degradation due to sloping topography, not practicing proper soil conservation strategies, continues land preparation practices and limited vegetation cover. Tea can be identified as the dominant land use which covers 21.46 $km^2$of the study area. Tea grown lands are also contributed to land degradation as soil under tea gets exposed to varying degrees of erosion depending on the planting density, type of planting, method of pruning, and the extent of seedling tea lands with uneven vegetation cover. Soil loss caused by poorly managed tea cultivation seems to be equal to those of highly erosive crops such as tobacco and potato. This land use occupies 22.53% of total area. As agriculture is mainly dependent on season, seasonal variation in data acquisition has a lot of influence on the results. In Kothmale area *Maha* is the major vegetable cultivation season. Due to the lack of availability of good quality images, the image used for this study was acquired on 30 August 2013 which is the end of *Yale* season. Therefore an underestimation of total fields under crops can be expected in this classification process.

We conducted an assessment of classification accuracy of land use using an independed data set of land uses idenfied on Google Earth imagery.

Table 2: Kappa analysis results

Land use types	Reference total	Classified total	User's accuracy (%)	Producer's accuracy (%)
Home garden	29	23	68.97	86.96
Crop field	6	5	83.33	100.00
Forest	11	11	100.00	100.00
Water	5	5	100.00	100.00
Tea	23	24	82.61	79.17
Paddy	9	6	66.67	100.00
Scrub land	17	26	94.12	61.54
Overall accuracy	82%			
Kappa Index	0.78			

The overall classification accuracy was 82%, with an overall kappa statistic of 0.77802. According to the Kappa interpretation table the value lie between 0.6 -0.80 level. Therefore the classification results have substantial agreement with producer data. It can be concluded that the accuracy of classification was acceptable; however it could not get higher accuracy because of some limitations. The main limitations of the classification were the seasonal influence, topographic effect and cloud effect. Clouds and haze are a common problem in mountainous and tropical environments where in Kothmale. Topographic characteristics of the landscape, such as slope and aspect, in combination with the solar zenith and azimuth angles, result in illumination differences within a satellite image. As classification was done by using spectral reflectance these effects lead misclassification.

The classes “forest” and “water” were extracted without any misclassification with relatively higher producer’s and user’s accuracies. The other classes such as “home garden”, “tea” and “scrub lands” were prone to some amount of misclassification with relatively low producer’s and user’s accuracies. Tea lands were misclassified somewhere as home gardens or crop fields. We can also notice that scrub lands in riverbed is misclassified somewhere as home gardens. This is mainly because those classes have similar spectral reflectance.

Field survey was also conducted to collect the ground truth data of different LULC classes. 20 LULC reference data was collected in selected Grama Niladari Divisions (GNDs) within the study area and apply the accuracy assessment. This accuracy assessment also gave the similar result like with higher resolution Google images. Error matrix table and Kappa analysis results in appendix showed the results obtained with field collected reference data. It gave 85% overall accuracy with 0.8125 Kappa coefficient. Though the two LULC classes, water and forest couldn’t found within the field data collected GNDs only five LULC classes were taken into consideration.

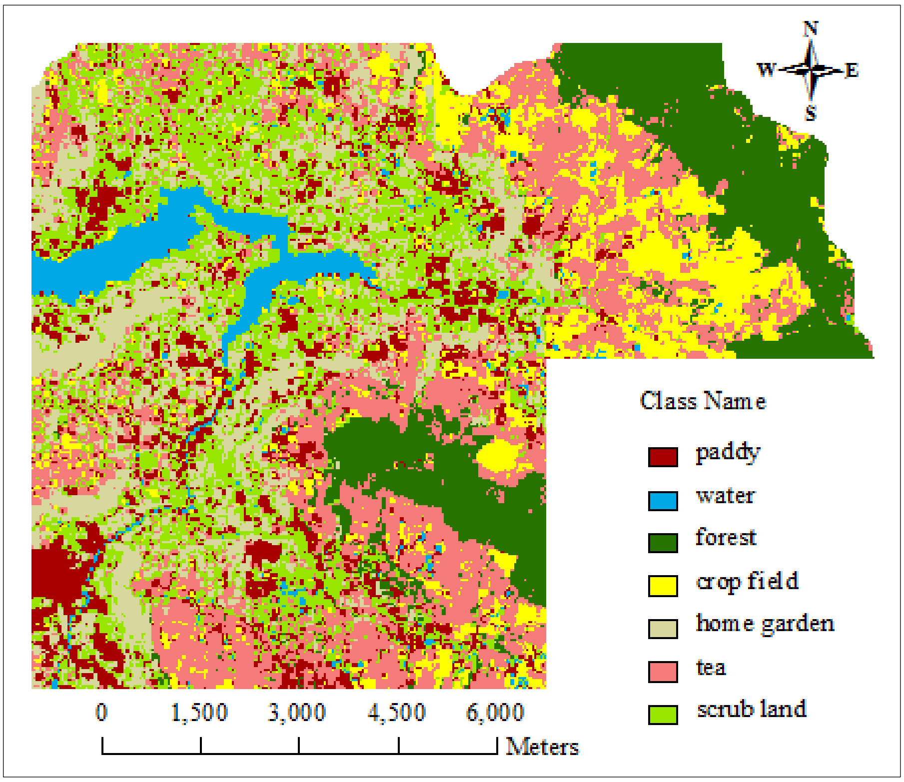

Figure 4: Land use/cover classification map

Elevation raster map which derived using DEM (Figure 6) showed that the reservoir surrounded by the mountain ridges and reservoir is located in low elevation. Very high elevation area, which are greater than 2,000 m are few but most of area lie in between the elevation range of 700 m – 1,200 m. It can be concluded that surrounding area, which are under destructive cultivations showing greater propensity for increased destruction and degradation of the top soil and reduce the capacity of reservoir.

We tested the accuracy of the slope map by comparing slope calculated from the DEM and the slope measured at the field using a clinometer. Correlation test in R Statistical software was applied to field collected slope data (actual slope) and DEM derivative slope data (predictive slope)

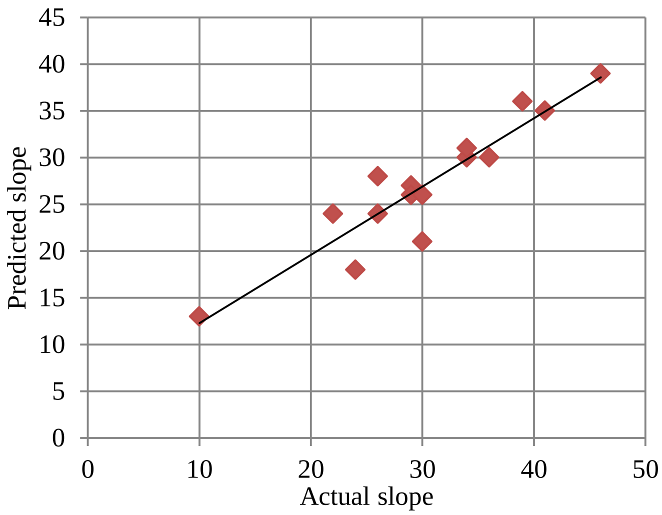

Figure 5: Relationship between actual slope vs predicted slope

Figure 5 shows the plotted variables and that indicates positive linear correlation between actual slope data and predicted slope data. A correlation coefficient of r = 0.9 (Pearson's product-moment correlation coefficient) was observed between two variables, which was indicated there is a strong relationship between the calculated and observed slopes The derived reclassified slope map indicated (Figure 7) that the area where slope greater than 60 percent is 16.17 km^2 which cover 17.0% of the study area which signifies potential risk for degradation.

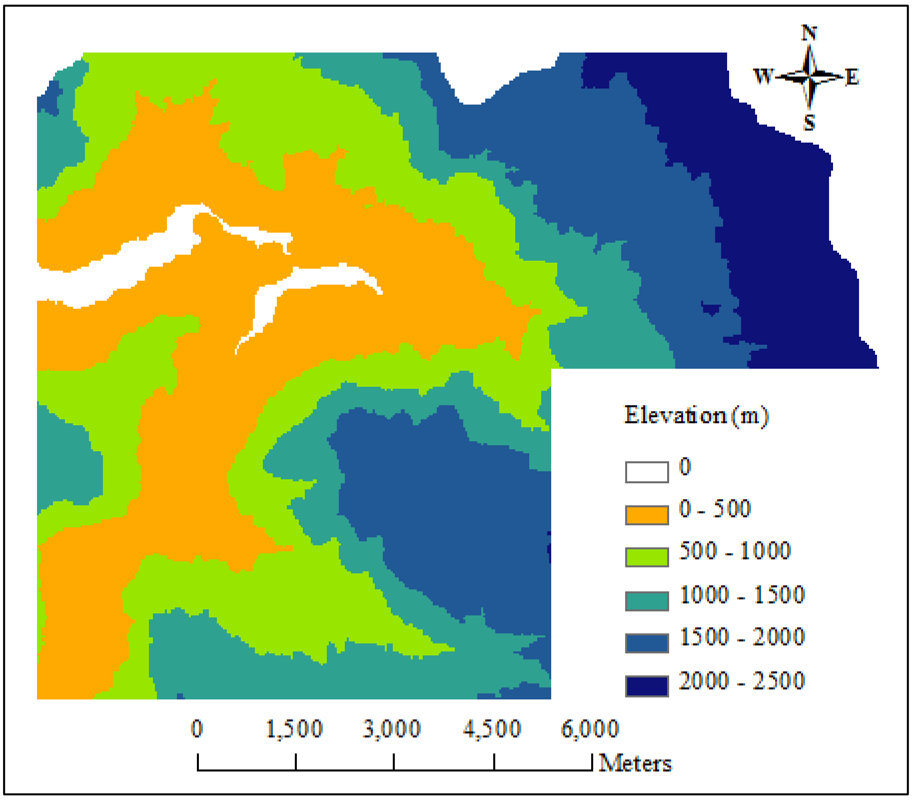

Figure 6: Digital elevation model

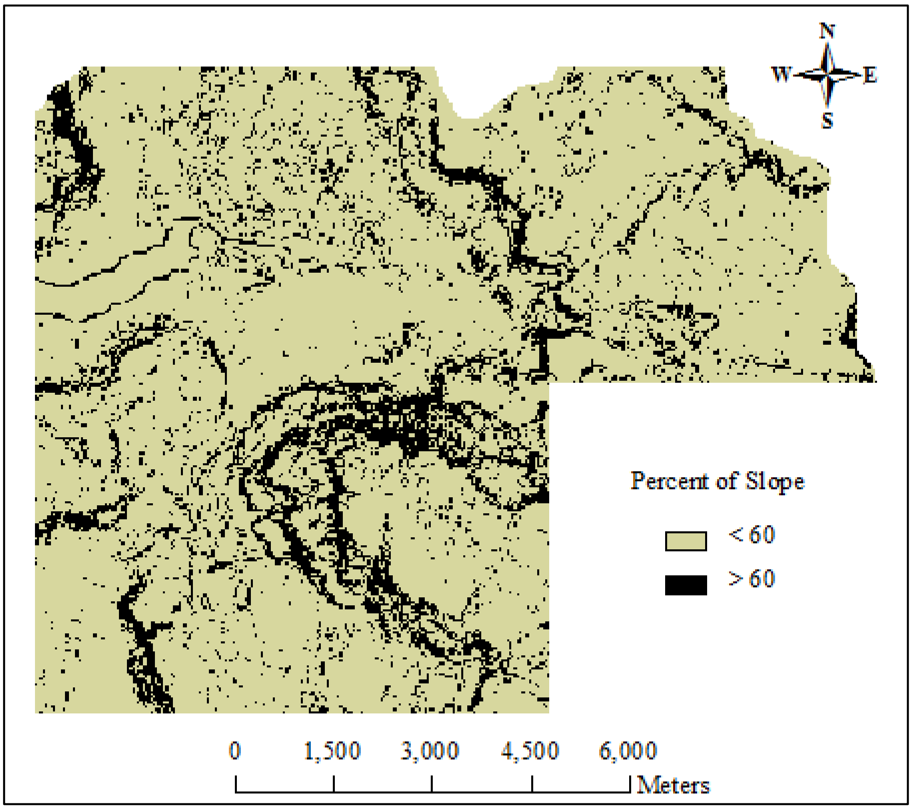

Figure 7: Reclassified slope map

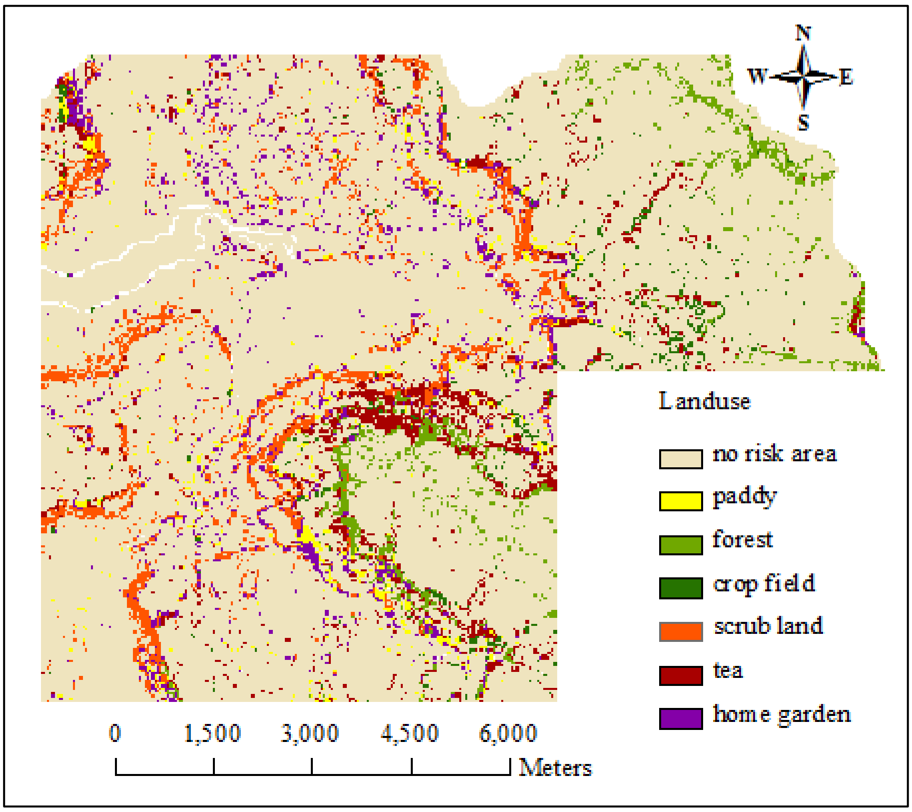

Figure 8: Distribution of different land uses on degradable lands

Table 3: Extent of the land over risk slope and the relative percentage of the total degradable land area

land use/cover type	Area (km^2)	Area (%)
Forest	13.25	13.91
Scrub land	14.62	15.35
Tea	21.46	22.53
Paddy	11.30	11.86
Water	4.20	4.4
Crop field	10.84	11.38
Home garden	19.60	20.57
Total	95.27	100

.
According to the results of overlay analysis, 42.2% of land is non-degraded; covering an area of 684 hectares, comprising of dense forest, home garden and paddy lands. Scrub lands occupy 27.46% of vulnerable land having an area of 444 hectares. 23.62% of the land which occupy by tea cultivation is under degradation category having an area of 382 hectares, whereas 6.69% of land, which accounts for 107 hectares, is also under degraded category.

4. CONCLUSION

In the studied section of the Kothmale catchment area (95.27 km^2) the total vulnerable area for soil erosion which slope greater than 60% was calculated as 16.17 km^2 which was 16.97% of total study area. Total degradable area within the vulnerable area, of the study area was estimated to be 30.31%, which reveals 23.62% area used for tea plantation while 6.69% used for vegetable cultivation.

This study revealed that combination of Landsat 8 imagery and digital contour maps (1:10000) can be used to identify degradable lands at catchment scale with an acceptable accuracy.

REFERENCES

Bai, Z.G., Dent, D.L., Olsson,L., and Schaepman, M.E.(2008). Report on Global assessment of land degradation and improvement 1. FAO,ISRIC, Rome,Wageningen.

Food and Agricultural Organization (2000). Land Degradation in South Asia: its Severity Causes and Effects upon the people. FAO, Rome.

Gamage, H.(1998). Land Use, Collaborative Research Project on Optimal Land Use in Sri Lanka between La Trobe University and Ministry of Plantation Industries.

Hellden, U. L. F. and Stern, M. (1980). Monitoring land degradation in southern Tunisia: a test of Landsat imagery and digital data. IAFHE RSLResearch Report, Remote Sensing Laboratory, Institute of Agriculture Forestry and Home Economics, University of Minnesota.

Ministry of environment and Renewable Energy (2014). National Action Program (NAP) for Combating Land Degradation in Sri Lanka.

Pickup, G. (1989). New land degradation survey techniques for Arid Australia: problems and prospects. Australian Rangeland Journal **11**(2), pp. 74-82.

Stein, A. and Goudriaan, J. (2000).Spatial statistics for production ecology. Agriculture, Ecosystems &Environment**81**(1), pp. 1-3.

Sabins, F.F. (1987). Remote Sensing: principles and interpretation. Geographical Journal.**153** (3), pp. 423-425.