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Identification of Barren Land using Remotely Sensed Data

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ABSTRACT. Available resources for soil conservation are very restricted and therefore, it is necessary to utilize the limited human and physical resources effectively and efficiently in achieving the goals of land resource conservation. In view of this, identification and spatially delineation of the barren land or erosion prone areas are found to be very important. SPOT HRV data with intensive ground information collection was used for this purpose. Although direct application of satellite data for conservation planning was successful, it was found that a more comprehensive approach through satellite data, aerial photography and field observations are required in planning for the long term sustainability of the land resource at Hanguranketa.

INTRODUCTION

Land resource is primarily important in developing countries, particularly for countries like Sri Lanka where the majority of the people are either directly or indirectly dependent on agriculture for their livelihood. Therefore, in order to ensure the welfare of the nation, it is imperative to sustain the productivity of the land resource. Soil erosion is said to be the predominant cause of land degradation in many parts of the country. In these areas, loss of soil is aggravated by the prevailing steep topography, the presence of erosive rains, erosion susceptible soils, improper land use and land management practices (Stocking, 1985). Available resources for soil conservation are very restricted and therefore, it is necessary to utilize the limited human and physical resources effectively and efficiently in achieving the goals of land resource conservation. In view of this, it would be very useful if a methodology could be developed to identify the most erosion prone areas or barren land where the potential threat of land degradation is much more severe and intense so that the limited resources could be concentrated upon these areas for sustainable productivity.

Remote sensing satellites orbit the earth at a variety of altitudes from low polar (200 km) to high equatorial (36,000 km), and their sensors gather electromagnetic energy reflected, emitted or back scattered from part of the earth atmosphere system below the satellite (Ray, 1987). These techniques utilizes electromagnetic energy which ranges from short wave lengths ultraviolet through visible near infrared and thermal infrared to the longer wave length active radar and passive micro wave emissions. All of these wave lengths are applicable and useful for agricultural remote sensing. The development of remote sensing technology in terms of hardware, software, and the availability of multisensoral and multitemporal data provides better facilities in a wider range of choice to acquire the ground information from the space. Compared to the Landsat Thematic Mapper, SPOT HRV satellite provides higher resolution imagery which could be conveniently used for areas where land holdings of smaller sizes are common.

In this study, an attempt was made to utilize remote sensing techniques as a tool for identifying and spatially delineating the barren land or eroded areas. SPOT HRV multi-spectral data at 20x20 ground resolution was used as the basic information source in recognizing the spatial context of erosion prone areas with an intensive ground truth information collection.

MATERIALS AND NETHODS

Selection and description of study area

Isolated attempts at soil conservation on small holdings will not produce any meaningful results. Most resource conservationists would agree that land use and conservation management should be conducted on a watershed basis. Therefore, a small watershed at Hanguranketa (within the boundaries of Upper Mahaweli Catchment Area) was selected for this study. Location of Upper Mahaweli Catchment and the boundaries of the study area are shown in Figure 1. Extensive soil losses have posed a great threat not only to the agricultural sector but also to the inhabitants of this area. The study area also includes two major reservoirs in Sri Lanka namely, Victoria and Randenigala.

The study area covers an extent of some 375 square kilometers which encompasses a wide range of farming systems and natural

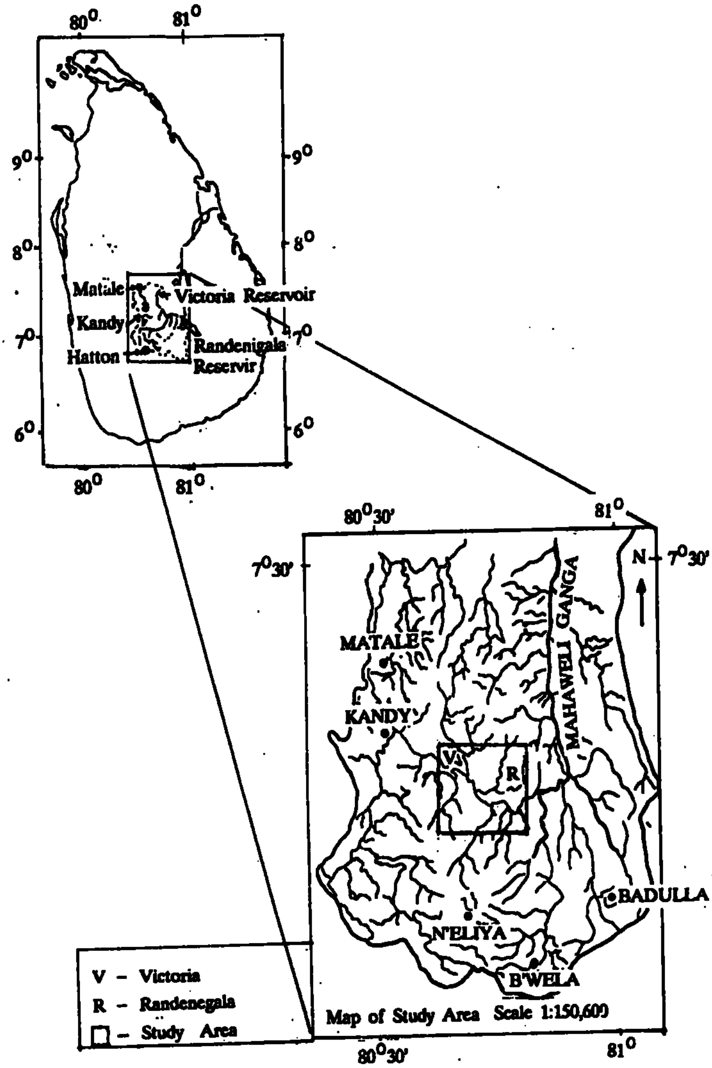

Figure 1. Location of the study area.

vegetation types. According to the Agro-ecological zone classification of the country, part of the area belongs to the Mid country wet zone (WM1), and the other to Up country wet zone (WU1) (Dormos, 1974). The elevation of the area varies from 300 meters to 1500 meters above sea level. Topography of the area could be classified as step slopes and moderate slopes. The predominant lithology is charnokite, and charnokite gneisses of the highland series together with the hornblende schists underlying a series of plan action levels. There are three major soil types found in the area namely reddish brown latosols, red yellow podzolic, and immature brown loams. Even though there is a marked effect from the orographic barriers, the rainfall distribution is fairly uniform throughout the year and ranges between 1500 mm - 4000 mm (Gibbon, 1990).

Satellite data acquisition

SPOT HRV data covering the study area was obtained from the Victoria Land Use and Conservation Project (VLUCP), Dangolla, Kandy, Sri Lanka. The cloud free digital data received on 26th August, 1986, was available, from three multi-spectral bands. The data from the Computer Compatible Tapes (CCT) was transferred and copied to the computer hard disk for processing. The Earth Resources Data Analysis System (ERDAS) software was used for the image processing. The schematic block diagram of the entire image processing methodology is shown in Figure 2.

Geometric correction

Geometric correction removes the image distortions caused by ground tract variations from the satellite platform and also the distortion due to earth rotation. The image correction from geometrical distortions is recognized as the first step in image processing due to the fact that most of the analytical functions in ERDAS could be employed only for geometrically corrected images (Premalal, 1990).

In the process of geometric correction, Universal Transverse Mercator (UTM) coordinates of thirty Ground Control Points (GCP) from the contour map at the scale of 1 : 63,360 and corresponding actual file coordinates of the image were input into a file created by

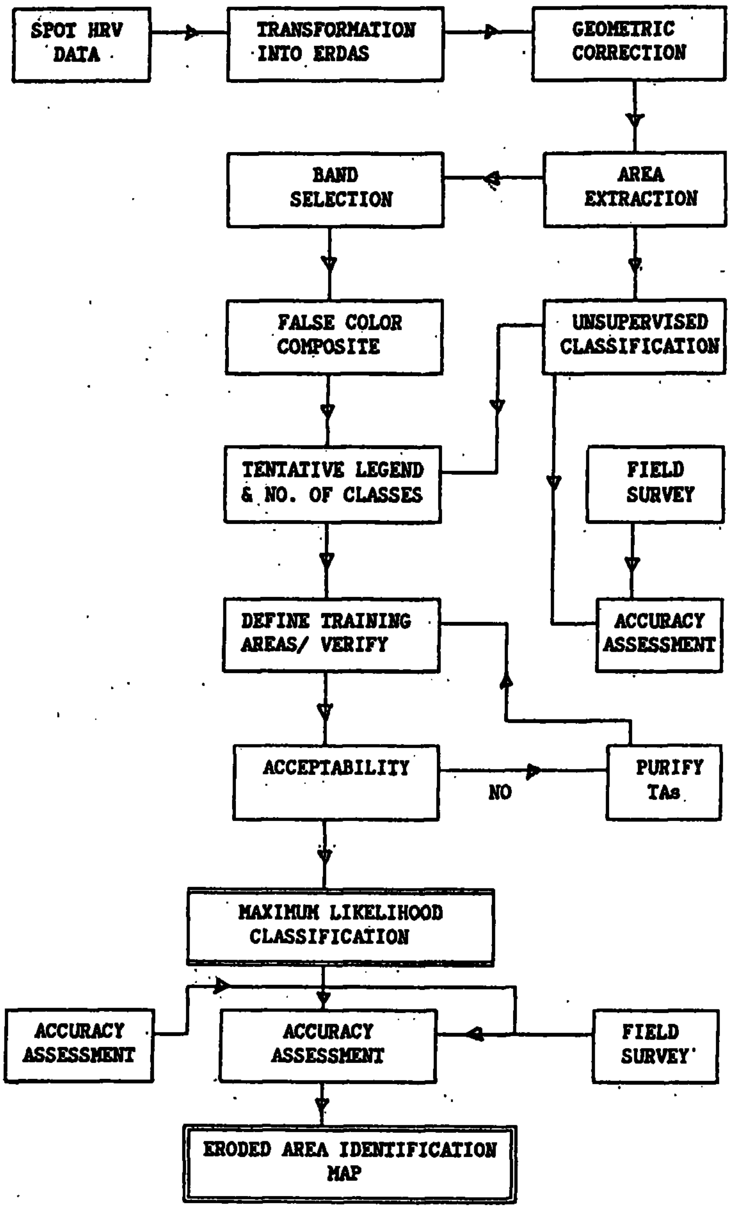

Figure 2. Block Diagram for Digital Image Processing.

GCP option in the Image Processing Menu of ERDAS. An error analysis of introduced GCP was conducted with the GCP Error Analysis Program (GCPERR). The default value of Root Mean Square (RMS) error (1.5) was used as the marginal level and twelve GCPs were rejected due to higher degree of error exceeding the default value. The entire image was then rectified by fitting the valid GCPs in RECTIFY option which is based upon the least square technique.

The study area was extracted from the geometrically corrected image in such a way that it includes two major reservoirs namely Victoria and Randenigala. The total number of pixels included in the study area was 1006x1006 which could be displayed on a full computer screen with background after reduction by factor 2. The extent of total study area was 371.5 square kilometers while background accounted for 33.2 square kilometers.

RESULTS AND DISCUSSION

Visual interpretation

It was decided to use all 3 bands for the identification of barren land because experimental results have shown that the accuracy of classification is higher when 3 bands are used when compared to that of a single or two bands combination. Blue, green and red colors were assigned to each band respectively in order to develop a False Color Composite (FCC) for visual interpretation. The image was enhanced using Histogram Equalization (HISTOEQ) to gain a better contrast. HISTOEQ enhancement technique does not require any inputs from the user and it subjects the image to nonlinear contrast stretching to the default range of 0-255 in all 3 bands. The developed FCC is shown in Figure 3.

Digital analysis

Digital analysis of remotely sensed data is said to be more precise and accurate in the sense that it operates in an interactive phase with both user defined conventions and computer derived information (Premalal, 1990). In this process, multi-spectral data of reflectance is clustered together according to the location of each pixel in the three

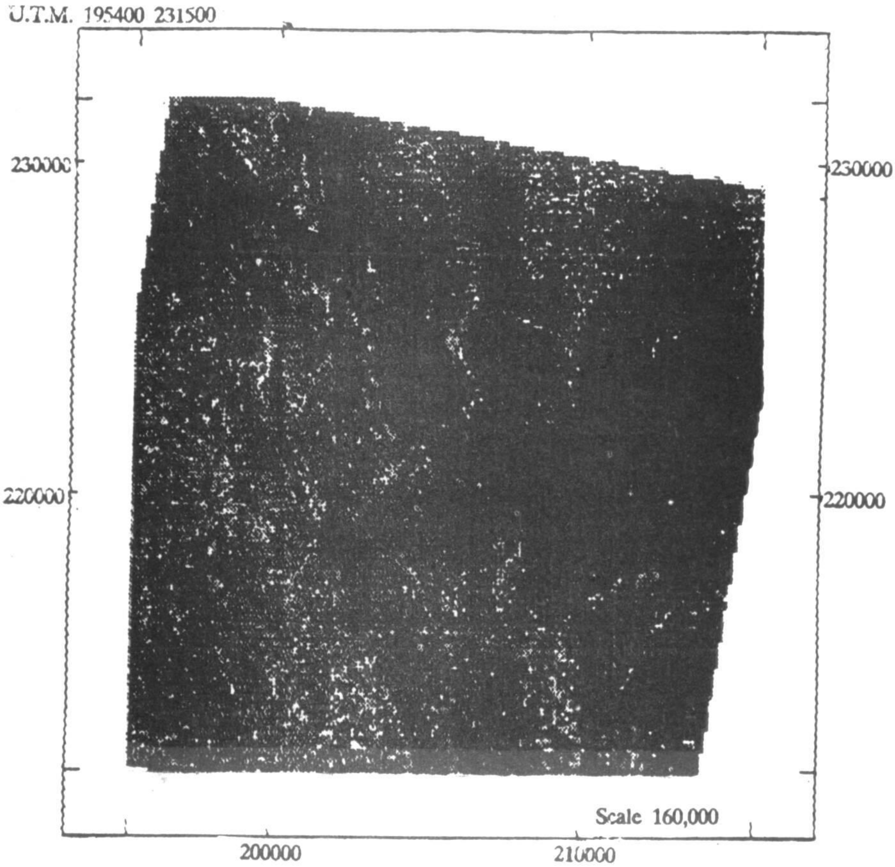

Figure 3. The fales color composite (1R,2G,3B)

dimensional multispectral space. There are two basic classification procedures in the digital analysis process namely, Supervised Classification and Unsupervised Classification.

Image data of all 3 bands were used in Unsupervised Classification and two different class numbers were introduced separately in order to have the option of selecting better clustering statistics. In this approach, Statistical Clustering (STATCL) option available in Classification Menu was employed and the number of classes defined were 4 and 6. Finally, the clustering statistics result from the classification with four classes, was adopted as the decision rule in identification of different field erosion levels in Supervised Classification. COLORMOD option was used in assigning color combinations of red, green and blue for the classified classes to produce the final GIS files in Unsupervised Classification. Unsupervised Classification provides good guidance for the Supervised Classification in identification of the erosion status on the image.

Supervised Classification is considered to be the best technique in identifying erosion status or the barren land of an image in the digital analysis process. The user is able to define a range of reflectance values by introducing training areas (samples from known barren land or any other particular land cover type) and make the computer to locate all other areas having similar values.

Based on the clustering statistics of Unsupervised Classification, four erosion levels were selected to be defined as Training Areas (TA). These were categorized as no erosion, low erosion, high erosion and water, taking the potential of hazard caused by each category into account. Extensive field visits were made throughout the study area to collect 48 TA locations. The selection of TA was made difficult due to the small size of land holdings, heterogeneous crop growth stages and poor infrastructural facilities. In this exercise, land use/land cover maps at the scales of 1:63,360 and 1:10,000 were also used as an alternate information source. The selected TAs were encoded into the FIELD option and QUICK ALARM signal was emerged to make a quick check over the collected ground cover information. SIGEDIT function was useful in discarding the sample locations which were found to be invalid. The validated ground cover information was added to form seven basic classes using the ADDSIG option in ERDAS. The added signatures were appended to a new file using the option APPSIG. Further editing on the signature file was possible with SIGEDIT function. Separate signature files were created in employing SIGNAME option.

Guassian Maximum Likelihood Classification (MAXCLAS) was adopted in classifying the 3 band image by introducing the ground cover information. This classification quantitatively evaluates both the variance and covariance of each category spectral response pattern when classifying each and every pixel assuming that the distribution of the cloud of points forming the category training data is Guassian or normally distributed.

The results of the Supervised Classification of the three band combination is presented in Figure 4. For visual identification, different colour combinations of red, green, and blue have been assigned to each class. The area estimation in hectares and the percentage of the total erosion status categories are summarized in Table 1.

Classification accuracy assessment

Although there is no simple, standardized, generally accepted methodology for classification accuracy assessment, it was decided to employ a confusion matrix through random field observation. In this assessment, the percentage of pixels from each class in the classified image correctly classified and erroneously classified in accordance with the ground truth information were estimated by a matrix which is a tabular representation of the accuracy assessment. The ground truth information required to formulate the confusion matrix was collected at 60 randomly distributed locations and UTM coordinates of each location with the respective status of soil erosion were tabulated and compared with the corresponding classified image category of erosion in the GIS file using CURSES option in File Management Menu. Confusion matrix formulated for the accuracy assessment of the eroded area identification is presented in Table 2.

CONCLUSIONS

From the results of the Supervised Classification, it can be observed that certain parts of the Mahaweli river and some of its tributaries have been classified as barren land. This can be clearly noticed in between

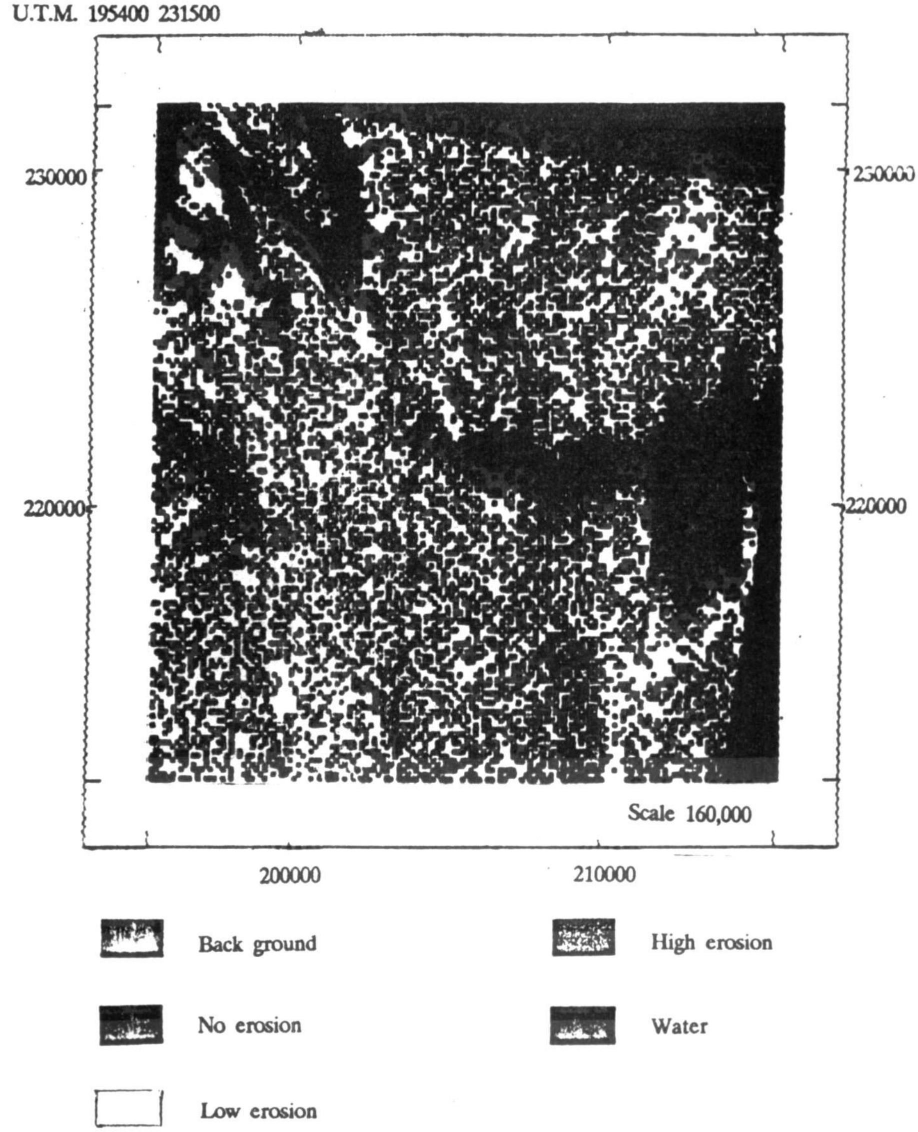

Figure 4. Eroded area identification map

Table 1. Results of the supervised classification.

Value	Points	Hectares	%	Description
0	83280	3331.200	0.00	Back ground
1	350922	14036.880	37.78	No erosion
2	374727	14989.080	40.35	Low erosion
3	122635	4905.400	13.20	High erosion
4	80471	3218.840	8.66	Water
Total	928755	37150.200	100	

Totals and percentages are based on non-zero points.

Table 2. Confusion matrix for accuracy assessment in supervised classification.

FIELD EROSION LEVEL	CLASSIFIED PIXELS ON THE MAP				
	1	2	3	4	TOTAL
1. No erosion	8	2	2	0	12
2. Low erosion	6	12	2	0	20
3. High erosion	0	2	5	0	07
4. Water	0	0	0	21	21
Total	14	16	09	21	60

Victoria and Randenigala reservoirs where the water level is relatively shallow due to the construction of the Victoria dam. The computer is unable to differentiate between the spectral reflectance of stream network with shallow water and that of barren land. An error of this nature could be circumvented by further purifying and acquainting large number of training areas. Since the computer follows the user defined conventions, care should be taken to introduce precise training area representation.

Since land use changes are constantly made at Hanguranketa, more time series data should be incorporated to obtain a higher degree of accuracy. The accuracy of the barren land identification could be further enhanced through a comprehensive training area selection which also includes training sites at poor infrastructural locations.

The identification of barren land or eroded areas would provide the basic spatial context for conservation planning. Although the same methodology could be applied island-wide in identifying barren land, facilities for certain modifications should be made available. It was also found in this study that the direct application of SPOT HRV data for conservation planning bears little significance due to the small size of land holdings, heterogeneous crop growth stages, and constant changes in management strategies at Hanguranketa. However, it is obvious that an integrated approach through satellite data, aerial photography, and field investigations would be a prerequisite in land use planning and management.

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