Tropical Agricultural Research Vol. 4 1992

A Deterministic Approach in Prioritizing Sub – Watersheds for Soil and Water Conservation: A Case Study in Hanguranketa, Sri Lanka

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ABSTRACT. The watershed management approach has been found to be very effective in soil and water conservation. However, in the case of large reservoirs, it becomes impractical to treat the entire watershed area as a single unit for conservation due to limited availability of resources. Therefore, it is imperative to identify the priority sub watersheds where soil conservation measures are urgently required for the sustainability of the land resource. In this study, a comprehensive methodology of a deterministic approach in synthesizing climatological parameters, soil variability and land cover information through remote sensing, FORTRAN – 77 programming and Geographic Information Systems (GIS) for the identification of sub watersheds is presented. Remote sensing techniques are used as a means of collecting data on spatial distribution. A FORTRAN programme is used to estimate the soil, land and climatic variability in numerical terms, and the GIS is adopted as the link between numerical estimations and non – spatial attributes. The procedure has been applied for a selected watershed in Hanguranketa, Sri Lanka.

INTRODUCTION

Isolated attempts at soil and water conservation on small, fragmented land holdings will not produce any meaningful results. Most of the Resource Conservationists would agree that land use and conservation management should be conducted on a watershed basis (Stocking, 1985). A watershed is an area from which run – off resulting from precipitation, flows past a single point into a large stream, a river, lake or an ocean. The terms watershed, catchment area and drainage basin are used in the same sense.

Watershed management programs are generally aimed at multiple objectives which include controlling run – off, utilizing run – off for useful purposes, reducing soil erosion and subsequent sedimentation, moderating flood in downstream areas, enhancing ground waters storage, and improving forest and fodder resources (Murty and Premalal, 1991).

A watershed may be a few hectares as in the case of a small stream or hundreds or square kilometers as in the case of a large river. In the watersheds of large reservoirs, it becomes impractical to plan the soil conservation work treating the entire area as a single hydrological unit due to the limited availability of resources. The recognition of the erosion hazard at a sub watershed level provides the basic guidelines in formulating a comprehensive methodology for the implementation of conservation strategies and planning effectively and efficiently. Remote Sensing technology could be conveniently used for the land cover assessment and a FORTRAN program could be effectively used for estimating model parameters and correlating them with non – spatial attributes in order to identify the existing erosion environment of the watershed (Premalal, 1990). An attempt to outline a procedure for identifying priority areas within a given watershed is presented in this paper. The procedure has been applied for a case study in Hanguranketa, Sri Lanka.

Description of the study area

A watershed of the Mahaweli river in Hanguranketa in the Central Province of Sri Lanka was selected for this study. The specific importance considered in the selection of the study area is that extensive soil losses in this area have posed a great threat not only to the agricultural sector but also to the lives of the inhabitants. It also includes two major reservoirs of Sri Lanka namely, Victoria and Randenigala. The entire area is about 375 square kilometers encompassing a wide range of farming systems and natural vegetation types. The elevation of this area varies from 300 m to 1500 m above sea level and the topography is moderate to steep slopes. This area is subjected to land degradation which demands for a comprehensive conservation methodology due to severe soil erosion and subsequent sedimentation.

APPROACH

Development of Thematic maps

Thematic maps of erosion contributing parameters viz. Slope map, iso-erodent map, soil erodibility map were developed for the study area. The contour map at the scale of 1:63,360 with 500 feet (165 meters) contour intervals was projected upon a grid sheet and the topology with respect to each spatial location was identified. A sub routine in FORTRAN was developed to calculate the slope at each geographical location with reference to the introduced UTM coordinates. The algebraic algorithm defined in FORTRAN identifies 5 basic slope classes *i.e.* 0-8%, 8-16%, 16-30%, 30-60% and more than 60%.

In an attempt to recognize the erosivity status of the study area, it was found that the recording rain gauge network was not extensive. An alternate approach was sought by developing a regression model which only requires mean annual rainfall and rainfall aggressiveness as basic inputs. This regression model was formulated based on the daily rainfall observation records available for 11 meteorological stations in the Mid and Up country of Sri Lanka (Wickramasinghe and Premalal, 1989). The developed regression model could be presented in the following order.

$$MAE = 5.62\ MAR + 92.32\ RA - 11754.49$$

where MAE = Mean Annual Erosivity in joules per square meter
MAR = Mean Annual Rainfall in mm. and
RA = Rainfall Aggressiveness Index

A sub-routine in FORTRAN was developed to estimate the erosivity status at the selected seventeen non-recording type rain gauge stations with reference to the spatial locations. The input file for this sub-routine consists of monthly data of rainfall and rainfall aggressiveness for twenty consecutive years.

The susceptibility of soil towards erosion was assessed by the nomograph introduced by Wischemeier *et. al.*, (1971). A sub routine in FORTRAN was developed transferring the statistical correlation found in the nomographic representation into numerical estimates. The input file for this sub routine consists of soil properties and characteristics such as textural composition, organic matter content, permeability and soil structure. In this study, soil from twenty sampling locations was obtained and a series of laboratory analyses was conducted to determine the input parameters for the sub routine.

Image processing

SPOT HRV satellite data in digital format covering the study area for a cloud free day (August 26, 1986) was obtained from Victoria Land Use and Conservation Project (CLUCP), Kandy, Sri Lanka.

Processing and interpretation of data were conducted on a 386/20 NEC-APC-IV personal computer with a math co-processor, number nine graphic card, frame store and 130 megabyte hard disk. A 14 inch colour monitor was used for graphic display and a 24 by 36 inch (60 by 90 cm) digitizing table was used for thematic data input. Earth Resources Data Analysis System (ERDAS) developed by Erdas Inc. Atlanta, Georgia, USA was the available image processing and GIS software. It was decided to classify the land use/land cover into 7 broad classes namely water, paddy, forest, tea, home gardens, other crops and bare lands. The potential of erosion hazard caused by each land use category was taken into account in this classification.

During the process of classification. several problems were encountered that influenced its accuracy. Small land holdings which generated the spectral reflectance of mixed land use mainly accounted for lowering the classification accuracy. Erroneous interpretations occured due to the land use changes that had occurred during the period between the image acquisition date (August, 1986) and the date of ground truth collection (August, 1990) lead to an erroneous interpretation. Further, in some cases, poor access made in some cases, the ground truth collection impossible. Changes in soil moisture regimes, heterogeneity of crop growth stages are some other factors which directly influenced the reducing of the degree of classification accuracy.

Determining the erosion environment

In determining the erosion environment at sub watershed level, 18 sub watersheds within the study area were delineated on 1:63,360 scale contour map. The delineated watershed boundaries were digitized into ERDAS along with the drainage network in each hydrological unit.

The derived parameters of erosivity, erodibility and slope were transformed into the GIS mode in ERDAS maintaining the exact geo-references. The classified SPOT HRV image of land use/land cover was also imported into the GIS control mode in ERDAS. The number of classes were limited to 5 in erosivity and slope while erodibility and land use/land cover classes were set to 7. The contribution of each factor towards soil erosion potential was assumed to be equal for convenience.

Information available on each erosion contributing parameter was transferred upon the boundaries of the delineated sub watersheds to identify the erosion environment at each hydrological unit. The composite map representing the erosion hazard profile was reclassified into 4 basic classes of soil erosion namely water, no erosion potential, low erosion potential, high erosion potential. Factorial scores were assigned to each category of erosion in order to represent the magnitude of the hazard.

A quantitative estimation of erosion hazard at each sub watershed was achieved by assigning factorial scores to the number of pixels at each category representing their erosion potential. The numerical values obtained were normalized to 100 and the priority sub watersheds were identified accordingly.

The priority sub watershed identification was totally based on the number of pixels at each erosion category and also depends upon the factorial scores commissioned to each category. Better results could be obtained by introducing proportional area criteria into the employed formula since it takes into account the specific significance of aerial extent and it leads to turn out a more flexible algorithm which would not deviate from practical feasibility.

CONCLUSIONS

Remote Sensing, FORTRAN programming and GIS technology provide the facilities for the collection and interpretation of the relevant data within their spatial and topological context. This exercise is much more convenient when planning soil conservation measures for relatively large watersheds. The sub watershed scenario adopted for this study, clearly indicates the areas where the conservation strategies are urgently needed to be implemented. The same methodology could be applied elsewhere but priority contributing parameters should be well understood and clearly defined. The identified priority sub watersheds should be considered as individual hydrological units and comprehensive monitoring and evaluation program should be conducted in order to assess the degree of conservation after the individual sub watershed conservation strategies are established.

ACKNOWLEDGEMENTS

The valuable advise and support extended for the successful completion of this study by Dr. Apisit Eiumnoh, Dr. V.V.N. Murty, Dr. Kaew Nualchawee, Dr. Hugh Gibbon, Dr. K.G.A. Goonasekera and Dr. Amala Jayasekera are gratefully acknowledged.

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