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A CASE STUDY OF SOIL EROSION DETECTION BY DIGITAL ANALYSIS OF THE REMOTELY SENSED MULTISPECTRAL LANDSAT SCANNER DATA OF A SEMI-ARID LAND IN SOUTHERN INDIA

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ABSTRACT

Soil forms one of the vital natural resources in that it is useful for agricultural and engineering purposes as the Chief plant supporting material for producing food and fibre and as construction material for raising buildings respectively. Soil erosion caused by the action of wind, water, ice and gravity over a terrain requires, therefore, prompt detection and implementation of proper preventive/remedial measures to conserve the soil resource. Soil inventory to assess its quantity and quality by the conventional field survey methods consumes considerable manpower with time and money and the remote sensing technology offers in this context, a powerful tool to achieve the objectives of producing meaningful regional soilscape maps quickly with less amount of survey inputs.

The Landsat frame under study was of February 27, 1973 and the digital analysis was done at LARS using LARSYS software package in March - April, 1977, followed by post field check in September, 1977. While carrying out the original and limited objective of doing a quantitative exercise for assessment of Bhavani dam waterspread area and its irrigated lands by digital analysis of the Landsat scanner data, it was incidentally found out that a long stretch of land lying for length of about 70 miles and for a width of about 2 to 5 miles was revealing very light tone on the imagery. The prefield presumption for the occurrence of possible soil erosion was confirmed by post field observations. The predominant pegmatite rock associated with country rocks in the area was found undergoing disintegration due to weathering phenomenon and the quartz fragments and the mica flakes in the washed debris with high albedo revealing light tone on the imagery.

The paper discusses, among other things, the methodology adopted in the digital analysis related to soil erosion studies using the LARSYS unsupervised clustering algorithms.

I. INTRODUCTION

Soils are produced by the interaction between the climate and rocks and meaningful soil categories are based primarily on such features as soil texture, parent rock, slope and drainage characteristics. The agricultural classification is plant supporting fertility oriented and the engineering classification is of strength oriented to sustain loads when used as construction material.

Erosion patterns are related to wind, water, ice and gravity acting on the materials of the earth's surface and all landforms are modified during and after development by one or more of these agents. The eolian, alluvial, glacial or residual soils produced after the chemical and mechanical weathering of base rocks by the action of the atmospheric agents have direct bearing on the landform characteristics. Most landforms are generally erosional; landforms by wind erosion are produced in dry lands where plant cover is sparse or lacking. The percolating water tends to dissolve all the non-resistant rocks. The minerals react in the chemical process of oxidation, hydration and carbonation and the elements released by the processes are removed. The action of percolating water is accelerated by the rocks joints and fissures which provide avenues for movement of water to form groundwater table. The slope helps the mechanical disintegration of the rocks; freezing and thawing phenomenon assist the breaking and loosening of the rock matrix.

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In the conventional photointerpretation, photocharacters such as tone, texture, shape, size, etc. are used to identify soils. The most important photo recognition features of earth materials are topography, drainage, erosion, soil tone, vegetation and land use. Irregular wavy flowing patterns indicate steep slopes and erodible soils; light photo tone indicates low moisture, porous materials and topographically elevated portions contain coarser soils. V shape gullies reveal coarse grained soils like sand, gravel and fine grained soils like silt and shale by U shape gullies.

In the present day remotely sensed multispectral data analysis, the spectral response characteristics of soils play an important role in the identification of the soil categories. A good amount of research has been carried out in this direction. Automatic data processing techniques could be used very effectively to delineate and map surface soil areas containing different levels of soil organic matters; the type of cultivation practice, ploughing pattern change the reflectance characteristics of soil (Kristof et al).

The organic matters content is inversely proportional to spectral reflectance. The middle infrared region is the best region for establishing meaningful relationship between physical, chemical and genetic characteristics and spectral response of soils. Soil colour has a major influence on the reflectance and variation in soil moisture and surface conditions also modify the reflectances; crusted soils have higher reflectance values than rough surface soils; dry soils reflect more light energy than the wet soils. Greatest success has been achieved when variations in spectral response within a soil type are smaller than the variations between the soil types (Baumgardner et al).

The fine grained rocks reflect lesser amount of light energy than the coarse grained rocks (Farrokh Barzegar).

Natural vegetation can significantly mark and alter the spectral response of the ground as measured by air craft and space craft multispectral scanners; the significance of the vegetative cover depends on the amount and type of vegetation and the spectral response of the ground. Low albedo minerals are the most significantly affected and may be altered beyond recognition with only ten per cent green vegetation cover (Barry S. Siegal et al).

Soil differences have a more pronounced influence on the spectral properties of grass land than on crop land (F.C. Westin et al).

Greater soil - green vegetation contrast occurs in MSS 6 (0.7 to 0.8 μm) than MSS 7 (0.8 to 1.1 μm) of Landsat (Compton J. Tucker et al).

II. STUDY AREA

The Landsat frame ID 1219-0439500 of February 27, 1973, was considered for the analysis. The subset of the frame area bounded between the lines 1300 to 2200 and columns 550 to 2500 was taken up for digital analysis. The general ground truth informations about the area are:

The subset area is a part of Bhavani and Noyyil river sub basins. The area of study is geologically classified as hard rock area adjoining eastern side of the western ghats. It was tectonically disturbed. The depthwise material distribution is that surface soil is underlain by weathered rock mantle lying over fissured and jointed rock below. The average annual rainfall is about 600 to 700 mm. The rainfall occurs during north-east and south-west Monsoons. The average daily evaporation ranges between 5 to 7 mm. The average daily temperature ranges from a minimum of 20° to 33°C. The average daily relative humidity is about 80%. The daily average bright sunshine hours is about 5 to 7 hours. The elevation of the area is between 1000 to 1500 ft. above MSL. The average wind velocity is about 2 km/hour. The drainage is of dendritic type. Soil is generally red gravel, sand with quartz; the soil cover ranges from negligible thickness in the upper reaches to about 4 ft. in the lower down valleys. Paddy and Sugarcane, groundnut, millet are raised in the dam ayacut area. In the rainfed upland areas dry cultivation is sparsely carried out.

III. METHODOLOGY ADOPTED

Visual study of the Landsat imagery helps a long way in the effective digital analysis. Hence, the study area was projected in the digital display screen using the image display algorithms of the LARSYS. Black and white photo prints and colour composites using blue, green, red filters were then generated with the polaroid camera. In black and white imagery and the colour composites, a patch of land on the right side slope of the Bhavani River basin appeared to possess high albedo revealing light tone with good contrasted boundary line. The colour composite re-

vealed green vegetation in red, urban and barren lands as bluish, harvested and moist lands as greyish and water in dark tones. From the undulations and sparse vegetation observed in the light tone revealing patch, it was tentatively concluded to be due to active soil erosion occurring in the area; there was possibility for removal of top soil exposing the bottom horizon consisting of high light reflecting rock matrix. Line print outs with alpha numeric characters were generated for the study area using picture print function of the LARSYS. Fifteen training areas were selected, clustered and statistics obtained for fifteen separable classes. Then, the area was classified for fifteen classes, using four channels. The sum of mean intensity values of the four channels was found to vary from 201.93 for high light tone area to 53.35 for water body classes. The ratio of visible to infrared channel values varied from 1.2 for high light tone area to 4 for water body classes. A colour coded map for the fifteen classes was prepared and in this map, the pronounced light tone class was having clear boundary line.

IV. ANALYSIS

The study area was scanned by the Landsat in February 27 of 1973 and it was digitally analyzed in March - April, 1977. With no ground truth information or large scale air photos on hand for collateral analysis, it was decided to adopt unsupervised classification procedure with the LARSYS clustering algorithms. This approach suits well to such a situation to prepare thematic maps by digital analysis, the themes or classes being checked later on in the field. In the month of September, 1977 the target area of light tone was checked in the field. It was observed that the target area lying on the right side slope of Bhavani basin ridge line has fairly steep sloping ground ranging from 1/25 to 1/100 in slopes; vegetation was sparse; the rock outcrop in the area was of pegmatite, mainly consisting quartz and feldspar associated with country rocks; the red gravelly soil cover was thinning out and the bed rock, exposed obviously revealing active soil erosion occurring in the area. The local gullies having typical V shapes and straight alignments wash down the weathered broken rock debris along with soil. Tropical climate with meagre rainfall and undulating sloping terrain contribute to the weathering processes. Since wind is not blowing with high velocity, rain water alone is responsible to transport the washed debris in the area.

The reason for such high light reflectance was analyzed and interestingly found out that during the weathering and transportation processes, the quartz and mica materials scattered all over the area act as innumerable tiny mirrors reflecting high percentage of incident light energy to the satellite sensors and this caused light tone in the black and white and colour composite photographs.

V. CONCLUSION

The map generated by the digital analysis of the Landsat MSS scanner data revealed the active soil erosion occurring in the basin area, which in turn, help in suggesting the necessity for proposing suitable soil conservation remedies to control the soil erosion phenomenon in the area. Analysis of the sequential Landsat scanner data obtained for a few more years continuously may help to compute the rate of horizontal soil erosion in the area and also quantify the weathering of the parent rock in the area in time and space.

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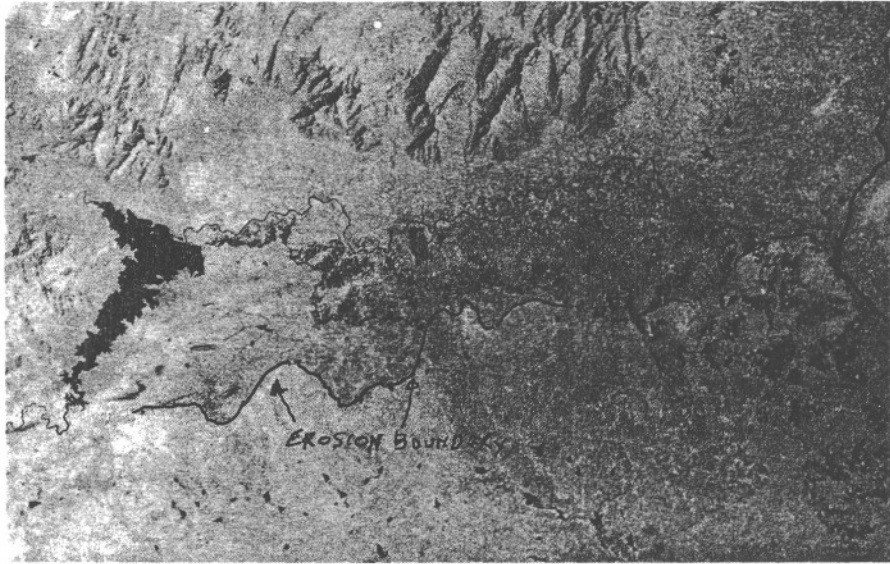


FIG. 1. LANDSAT IMAGERY REVEALING
SOIL ERODED AREA.

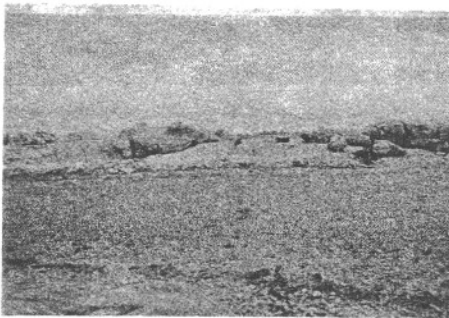


FIG. 2. WEATHERED ROCK AND SOIL
ERODED AREA PHOTOGRAPHED
DURING FIELD CHECK.

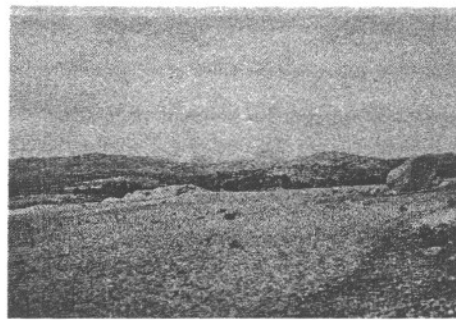


FIG. 3. WEATHERED ROCK AND SOIL
ERODED AREA PHOTOGRAPHED
DURING FIELD CHECK.

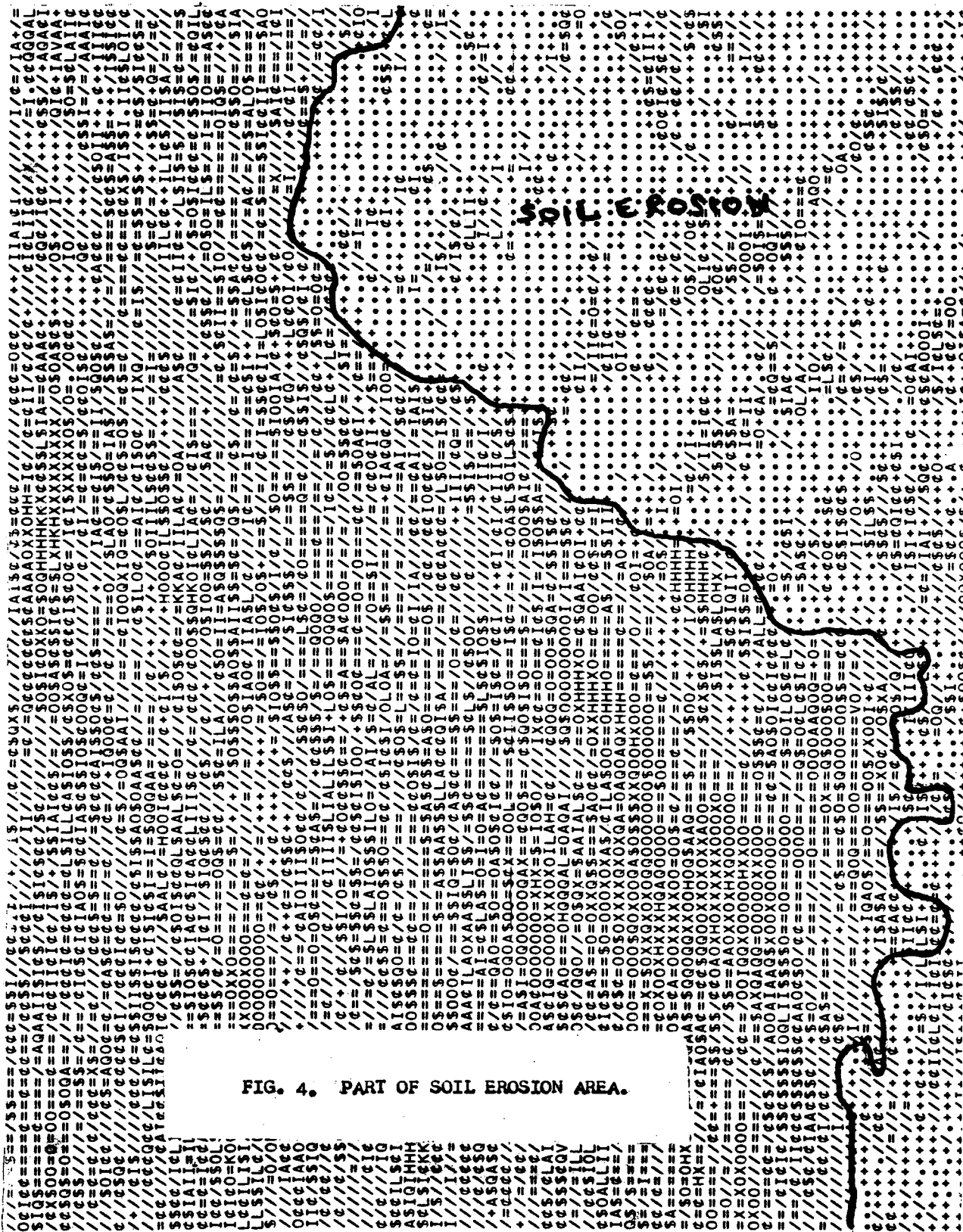


FIG. 4. PART OF SOIL EROSION AREA.

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Stevan J. Kristof earned a doctoral degree in Agricultural Sciences at Belgrade University, Yugoslavia and an M.S. degree in Plant Physiology at Purdue University. He joined the staff of the Laboratory for Applications of Remote Sensing (LARS) in 1967 and has been instrumental in soil studies there. He first demonstrated that soils could be mapped with an automatic technique, later applying the same technique to water, soil color, soil organic matter, moisture, clay, silt, sand and free iron contents, using data obtained by Apollo IX and Landsat. Presently he is assisting in the development of a detailed soil survey of Ford County, IL and a land resources inventory of the Big Desert area of Idaho using MSS data.