LAND DEGRADATION ASSESSMENT IN THE AFRAM PLAINS OF GHANA - A CASE STUDY

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ABSTRACT

Many areas under development in Ghana are susceptible to soil erosion and therefore require extensive management in order to preserve soil resources. Conventional field techniques for identifying and monitoring potential problem areas are slow and inadequate and need to be supplemented.

A potential problem area in Eastern Ghana which is subject to erosion as a result of its shallow, sandy soils was assessed for its susceptibility to land degradation through soil erosion.

Nine (9) landcover classes were established using ERDAS (EARTH RESOURCE DATA ANALYSIS) and ELAS (EARTH LABORATORY ANALYSIS SOFTWARE) to classify the Landsat-4MSS generated on 24th January, 1987.

Principal Component Analysis (PCA) and Tassled Cap Transformation were performed on the raw satellite data to increase the accuracy of the classification. This was assessed to test the level of accuracy achieved.

Matrix analysis revealed that 0.37% of the project area is susceptible to severe soil erosion hazard.

This research, undertaken during a training course by the author at EPFL/GRID (Geneva) in 1989, was designed to provide a technique for predicting which areas are most likely to be degraded in the future and demonstrated the advantages of GIS and Remote Sensing in resource management.

KEY WORDS: GIS, Remote Sensing, Land degradation, Assessment.

INTRODUCTION

A sound environmental management of a country's natural resources is crucial to its sustainable development. In most developing countries, however, gross negligence and poor management of the natural environment, coupled with the failure to recognise and act on their close inter-relationship leads to the alarming depletion of their resource base thus compromising the survival of the present and future generations.

It is to reverse this serious trend of environmental degradation by forging a new perception of environmental issues as a key strategy of the country's developmental efforts, that the Government of Ghana through the Environmental Protection Council, key ministries as well as relevant research and academic institutions, formulated an Environmental Action Plan (EAP) to harness all available data, establish new environmental data in new problem areas as well as systematically co-ordinate efforts between various implementing agencies. The successful implementation of this plan, based upon a concerted effort to create in the people a sense of responsibility regarding the safe and healthy maintenance of the ecosystem, is expected to add a new dimension to the nation's development efforts.

Presently, there are a number of reports dealing with various enviornmental issues in the country. What the EAP seeks to do primarily, is to ensure that all planning decisions are based upon impact predictions at the project planning stage. Thus information on the enviornment will henceforth be gathered, screened, compiled and analysed at the very beginning of the project planning stage, and integrated within the overall planning system so as to ensure a new integrated developmental approach that respects the inter-relationship between people and their environment.

For the purpose of such an integrated planning system, present conventional techniques are however inadequate, slow and costly. To redress these deficiencies, they could be supplemented by Geographical Information System (GIS) and Remote Sensing to ensure a more satisfactory spatial data acquisition and management.

The present report is therefore designed to demonstrate the operational use of GIS and Remote Sensing for environmental assessment studies in Ghana.

Ghanaian soils are susceptible to all forms of erosion. It has been observed that most of the soil nutrients are found within the top-soil up to 15-20cm and that the organic matter and plant nutrients content decrease sharply below the top-soil. These top-soils are lighter in texture, weak fine to medium crumbs and of fragile consistency. These are properties that make them erode very fast.

The Ghana Soil Research Institute (SRI) has reported alarming figures on erosion of affected areas. In the interior savannah zone which comprises of the study area, a land area of 35,172sq.km. is affected by slight-to-moderate sheet erosion, 27,306sq.km. by moderate-to-very severe sheet and gully erosion and 33,494sq.km. by moderate-to-very severe and gully erosion.

Available literature indicates that the removal of protective vegetation cover for woodfuel utilization and farming, has contributed much to the high incidence of erosion in the area. It has been estimated that women spend 1 hour per working day to gather firewood from fields.

The need to combine diverse information to consider a broad range of alternatives and supplement rather tedious and cumbersome manual techniques in addressing environmental problems which are dynamic in time and space, has been well documented. An automated GIS which is a tool for analysing and managing spatial data offers such an alternative according to user-defined specifications. This will ensure a more explicit and objective analysis, a more rapid examination of alternatives than can be accomplished through manual methods.

STUDY AREA

The study area (long 0^{o} 00' 0^{o} 15' West, lat 6^{o} 55' 7^{o} 10'N) is characterised by high temperatures, low humidity and moderate rainfall regime (1270 - 1770mm), with 2 rainfall maxima. The topography is level to near level. Except for the limited deep, well-drained medium textured piedmont drift savannah ochrosols, the bulk of the area is covered by groundwater laterites and groundwater laterites-ochrosol intergrates which are shallow to very shallow, poorly drained sandy loams of low fertility, and therefore prone to severe erosion hazard.

The vegetation for most parts is interior wooded savannah. The dual agricultural potential i.e. savannah and forest agriculture and its proximity to important food consuming centres in the south, namely Accra and Tema, has made it an important food-growing area.

There have been in recent times, widespread destruction of extensive tracts of vegetated land by bush fires as well as poor land management through indiscriminate exploitation of wood fuel, and charcoal burning in the area. To halt this serious trend, information concerning this environ ment will have to be gathered and organised for its effective management.

The project seeks to use Remote Sensing and Geographic Information System Technique to determine the land cover and to predict which areas are most likely to be degraded in future.

METHODOLOGY/RESULTS OF CLASSIFICATION

Spectral signatures were automatically extracted from the raw Landsat-4MSS generated on 24th January 1987, using both ELAS and ERDAS softwares.

Full maximum likelihood algorithms were then used to analyse each pixel independently of its surrounding neighbours, and subsequently assigned a class to which it had the maximum probability of belonging. This resulted in classified GIS files containing 13+(1) classes (ELAS) and 25+(1) classes (ERDAS).

One-dimensional spectral signatures were drawn afterwards for each class, with each one being compared carefully with spectral curves established by Lillesand and Kiefer (1979) and each reflectance class being assigned to a natural class.

To increase the accuracy of classification, the original four channel MSS data was transformed into new four-dimentional space, using the tassled cap transformation method developed by Kauth et al. This identified four new axes, namely the Soil Brightness Index (SBI), the Green Vegetation Index (GVI), the Yellow Stuff Index (YSI) and Non-Such Index (NSI) associated with atmospheric effects. The 13 Elas Classes were then used to mask the transformed image to produce 13 new image files. A 2-dimentional plot of GVI and SBI was established and used to reassign each of the 13 image files to their respective natural classes, as depicted in Fig 1.

The original MSS data was then subjected to a Principal Component Analysis (PCA) to ensure increased accuracy of the ERDAS classification. This was masked with the original 25 Erdas Classes to produce a new image file containing 25 classes.

A scatter plot using channels 2 and 1 was built to regroup the original Erdas classes, as shown in Fig 2.

To test the accuracy of the Erdas classification, a chi-square value of 7.78 representing a moderate elimination of misclassified pixels was assigned to each of the 25 classes, with all the misclassified pixels being assigned to a class value of zero (0). A summary run between the original Erdas GIS and the one obtained after thresh, revealed cloud cover, water bodies and shadows as classes with the highest number of misclassified pixels. (see Table 1).

Table 1. ERDAS CLASSES SHOWING % MISCLASSIFIED PIXELS

CLASS NUMBER	CLASS DESCRIPTION	% MISCLASSIFICATION
20	CLOUDS	26.74
22	"	19.89
8	"	15.31
18	"	13.76
2	CLEAR WATER	22.24
13	TURBID WATER	12.19
11	SHADOWS	31.03
1	SAVANNA GRASSLAND	2.68
3	FARMS	3.03
4	SAVANNA GRASSLAND	3.00
5	WOODED VEGETATION	2.17
6	VILLAGES/EXPOSED SURFACES	4.31
7	WETLANDS	2.39
9	WOODED VEGETATION	5.51
10	SAVANNA GRASSLAND	7.50
12	"	10.07
14	WOODED VEGETATION	1.38
15	"	5.38
16	SAVANNA GRASSLAND	4.27
17	WOODED VEGETATION	8.63
19	"	2.10
21	"	4.55
23	SAVANNA GRASSLAND	6.27
24	"	5.63
25	"	4.76

As depicted in Table 2, the final number of landcover for both classifications after recording were 1. Clear Water; 2. Turbid Water; 3. Wetlands; 4. Clouds; 5. Wooded-Vegetation; 6. Farms; 7. Savanna Grassland; 8. Villages/Exposed Surfaces 9. Shodows.

While ground truthing is required to establish the level of accuracy of this classification, these results will not only provide a solid base from which area-wide inventories could be established, but will also allow the regular updating of baseline information.

Table 2. ELAS AND ERDAS CLASSES

FINAL CLASS NUMBERS	CLASS DESCRIPTION	ELAS CLASS NUMBERS	ERDAS CLASS NUMBERS
0	BACKGROUND	0	0
1	CLEAR WATER	4	2
2	TURBID WATER	2	13
3	WETLANDS	11	7
4	CLOUDS	7,9	8,18,20 22
5	WOODED VEGETATION	3,10,12	5,9,14, 15,17, 19,21
6	FARMS	6,8	3
7	SAVANNA GRASSLAND	1	1,4,10, 12,16, 23,24,25
8	VILLAGES EXPOSED SURFACES	5	6
9	SHADOWS	13	11

ANALYSIS

A variety of analytical methods to assess land degradation in the study area were employed through synthesis of slope gradient, soil type and Normal Vegetation Index (NVI) files.

Slope gradient and soil type files were used in Matrix combination to bring out common and shared areas to give a precise distribution of various features within the study area.

This combination resulted in an intermediate file containing 6 (+1 for zero) classes. These classes were recoded and the resultant GIS used in a second matrix combination with NVI file to obtain a new file with 12 (+1 for zero) classes (See Table 3)

Table 4 obtained by recoding the results of the second matrix combination, shows that only 0.37% of the area is susceptible to severe erosion hazard.

The resulting map in Fig 3 depicts the spatial distribution of areas with slight, moderate and severe soil erosion hazard potential.

In this anlysis, slope was highly considered in the assignment of capability classes; hence all areas on steep slopes were assigned high values, because of their high soil erosion potential. The spatial distribution of this critical zone indicates areas that need to be closely monitored and extensively managed to preserve soil resources.

CONCLUSION

This study clearly testifies to the usefulness of GIS and Remote Sensing in resource management. This calls for its adoption in other susceptible areas in Ghana and its integration into our complex information system to help in meeting the needs of both planners and decision makers.

Table 3. RESULTS FROM MATRIX ANALYSIS OF SOIL/SLOPE/NVI

CLASS NUMBER	%	CLASS DESCRIPTION
0	0.00	BACKGROUND
1	0.23	SP.VEG,POOR SOILS,GENT SLOPE
2	0.01	SP.VEG, GOOD SOILS,STEEP SLOPES
3	0.57	SP.VEG,GOOD SOILS,MOD.SLPOES
4	6.16	SP.VEG,GOOD SOILS,GENT.SLOPES
5	1.88	MOD.VEG,POOR SOILS,GENT.SLOPES
6	0.02	MOD.VEG,GOOD SOILS,STEEP SLOPES
7	2.77	MOD.VEG,GOOD SOILS,MOD.SLOPES
8	33.59	MOD.VEG,GOOD SOILS,GENT.SLOPES
9	0.23	DEN.VEG,POOR SOILS,GENT.SLOPES
10	0.34	DEN.VEG,GOOD SOILS,STEEP SLOPES
11	7.31	DEN.VEG,GOOD SOILS,MOD.SLOPES
12	46.89	DEN.VEG,GOOD SOILS,GENT.SLOPE

Table 4. POTENTIAL SOIL EROSION HAZARD AREAS

FINAL CLASS NUMBERS	CLASS DESCRIPTION	%	FIRST MATRIX RUN RESULTS CLASS NUMBERS
0	BACKGROUND	0.00	0
1	SEVERE SOIL EROSION HAZARD AREAS	0.37	2,6,10
2	MODERATE SOIL EROSION HAZARD AREAS	52.74	1,3,4,5,7,8,9,11
3	SLIGHT SOIL EROSION HAZARD AREAS	46.89	12

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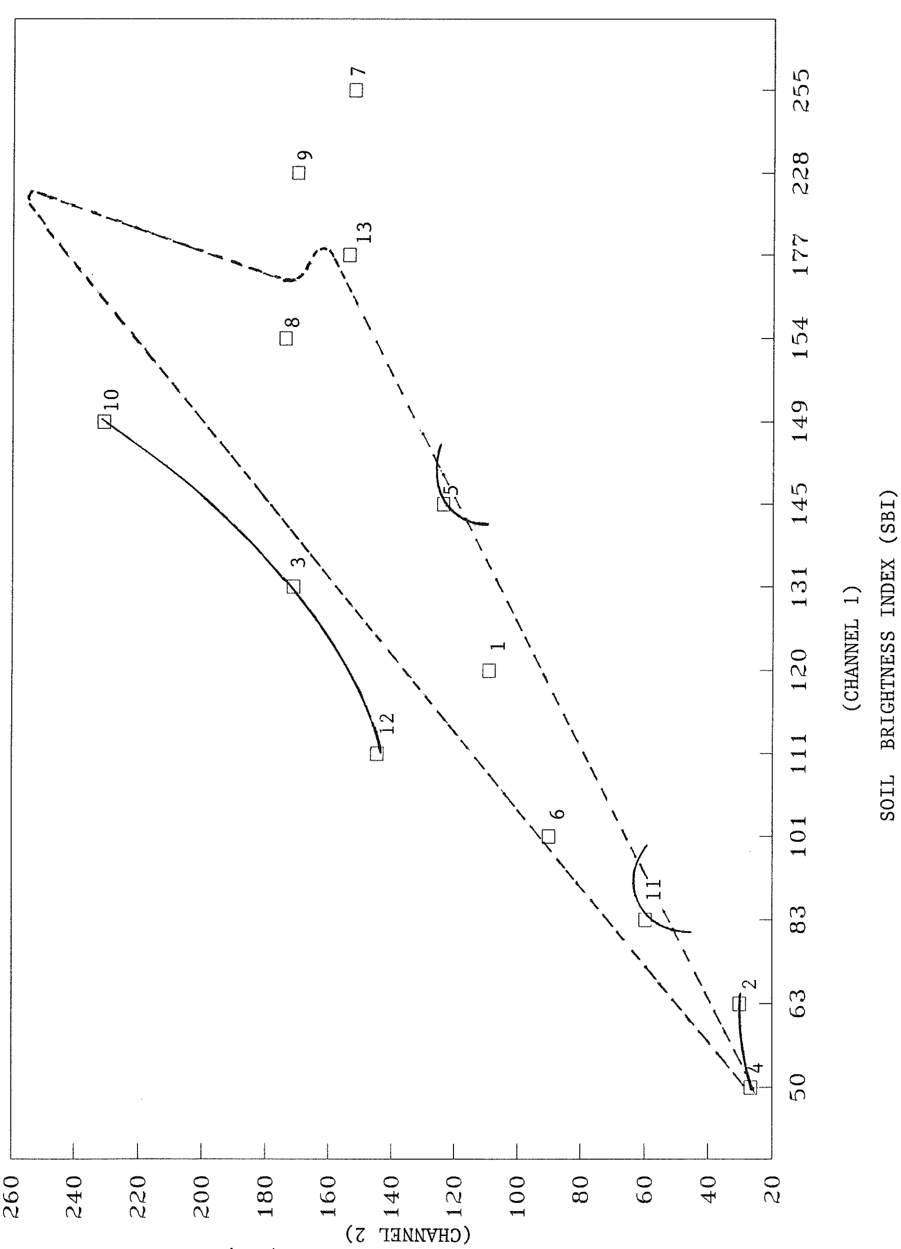

FIG.1 LOCATION OF VARIOUS ELAS LANDCOVER TYPES WHEN PLOTTED IN BRIGHTNESS - GREENESS SPECTRAL SPACE

FIG 2. LOCATION OF ERDAS LANDCOVER TYPES FROM PRINCIPAL COMPONENT ANALYSIS (PCA)

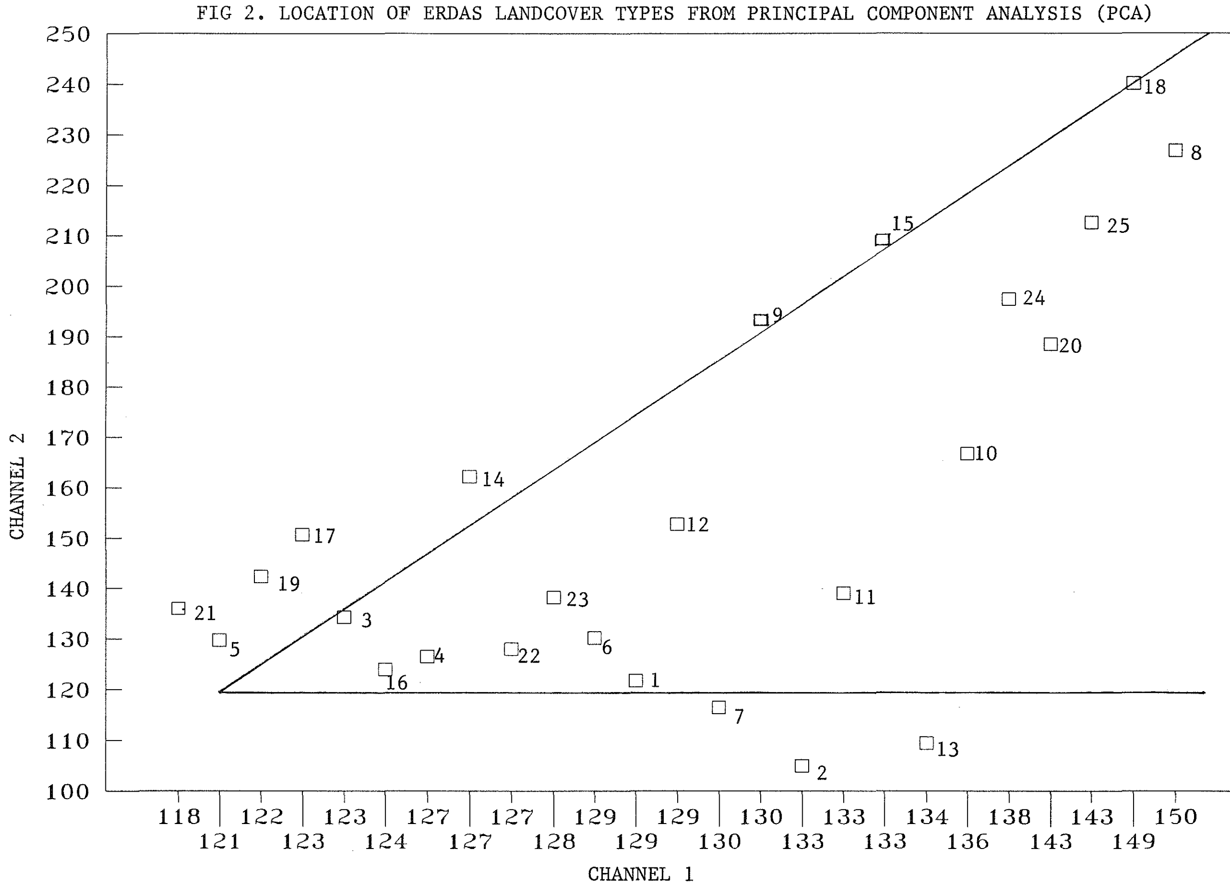

FIG 4: POTENTIAL HAZARD AREAS