Erosion Risk Assessment in Northern Ghana Through the Use of Remote Sensing and GIS: Preliminary Studies

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Abstract

This paper outlines the methodology used for an erosion risk assessment in Upper East Region, Ghana, using remote sensing and GIS, whereby both physical and socioeconomic parameters are taken into consideration. The study investigates the use of the scarce data sources presently available in the region. So far erosivity has been assessed from detailed studies of rainfall intensity and duration, topographic sheets act as a basis for a DTM and erodibility has been determined in the field in order to evaluate the use of existing FAO soil maps as erodibility maps. Studies of socioeconomic parameters and land use, determined by Landsat TM and SPOT, are currently being carried out and these data will together with the first mentioned be analyzed using ARC/INFO and IDRISI. A system like this allows monitoring of changes over time as well as makes it possible to model the effect of certain practices, e.g. cropping and soil management on erosion.

Résumé

Cette présentation met l'accent sur la méthodologie appliquée en vue d'une évaluation du risque d'érosion dans la partie orientale de la région septentrionale du Ghana; une méthodologie appuyée sur la télédétection et les SIG prenant en considération les deux aspects physique et socio-économique. L'étude a recherché l'utilisation des rares sources de données disponibles à présent dans la région. Jusqu'ici l'érosivité a été évaluée sur la base d'études détaillées à propos de l'intensité et la durée de la pluviométrie, des relevés topographiques servant de base pour un Modèle Numérique de Terrain; puis l'érodibilité a été déterminée sur le terrain afin d'évaluer l'utilisation des cartes pédologiques de la FAO en

tant que cartes sur l'érodibilité. Des études sur des paramètres socio-économiques et l'utilisation de la terre déterminée par SPOT et Landsat TM sont actuellement en cours et ces données seront analysées conjointement avec celles mentionnées précédemment en utilisant ARC/INFO et IDRISI. Un système tel que celui-ci permet le suivi des changements ayant lieu dans le temps et le rend également utilisable pour modéliser l'effet des cultures et des pratiques culturales sur l'érosion.

Background

Soil erosion by water and soil degradation in Ghana was noticed way back in the '30s and measures were taken to solve the problem (QUANSAH, 1990) but nevertheless in 1989 investigations done by the Soil Research Institute in Ghana revealed that at least 23% of the country was subject to very severe sheet and gully erosion, 43.3% to severe sheet and gully erosion and 29.5% to slight to moderate sheet erosion. Because of the continued increasing pressure on the land it is however expected that figures may be much higher (QUANSAH *et al.*, 1989). Especially in the Northern part of the country, erosion problems are severe and have intensified due to a combination of factors of both physical and socioeconomic character such as population pressure, poor farming practices, high erosivity, erodibility etc. (AGYEPONG and KUFOGBE, 1994).

In the Upper East Region of Ghana for example ADU (1972) reported soil loss of 90 cm of soil by sheet and rill erosion leaving only about 30 cm of coarse sandy loam and gravel above the parent materials. But even with small amounts of soil being eroded the higher concentrations of organic matter and plant nutrients in available form found in the eroded material being lost, is having devastating effects on the agricultural production.

A most effective and valuable tool to control and prevent erosion is erosion hazard/risk assessment, which according to MORGAN (1986) can be defined as "an identification of areas of land where the maximum sustained productivity from a given land use is threatened by excessive soil loss".

Generally, emphasis is put on the physical parameters whereas the socioeconomic aspects rather are neglected in spite of the fact that agricultural systems influencing erosion are a result of both the physical and socioeconomic environment (REENBERG, 1994; REENBERG, 1993a; FOLLY, 1993). Especially in developing countries, the major constraints to soil conservation are social (BLAIKIE, 1985; SAAKA, 1991).

So far the use of GIS and remote sensing in relation to erosion has been rather limited in Ghana, primarily due to lack of sufficient and up to date information. An example of land degradation assessment in the Upper East Region is given by GYAMFI-AIDOO (1987).

This study therefore outlines a methodology used for erosion risk assessment in Upper East Region, Ghana, whereby not only physical parameters are taken into account but also socioeconomic parameters are incorporated partly with the aid of remote sensing which finally ends up being analyzed and modelled upon in a Geographical Information System.

Study area

The study area of 20 by 30 km is situated in the Upper East Region of Ghana to the east, west and north of the regional capital Bolgatanga with a detailed study area for soil data measuring 10x10 km just east of Zuarungu (Fig. 1).

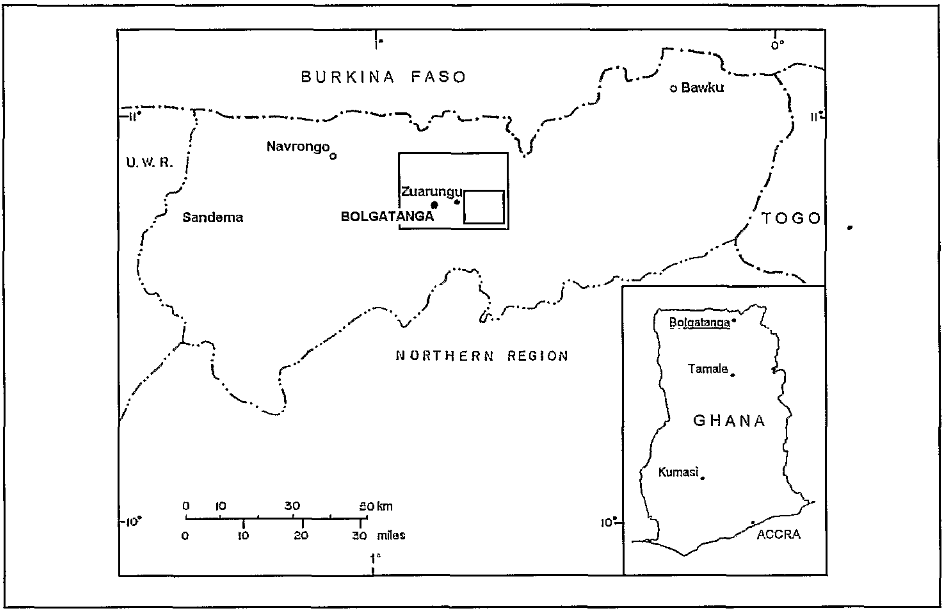

Figure 1. Location of the study area.

The average rainfall in the region is about 1,050 mm yearly but is characterized by large annual variations in both total amount as well as distribution but with the major part falling in between May and September. Due to average temperatures of 28.4°C, evaporation is very high (Metereological Services, 1988).

The upland soils in the area have been developed mainly from granites and are shallow, low in inherent soil fertility and with a low organic matter content, whereas the rest of the soils primarily have developed from Voltaian sedimentary rocks (IFAD, 1990; QUANSAH, 1990). ASIAMAH (1992) has classified the predominant soils according to the FAO-UNESCO legend of the soil map of the world as Luvisols, Lixisols, Cambisols, Leptosols, Vertisols, Plinthosols and Fluvisols.

The area falls within the guinea savannah zone characterized by a natural vegetation of savannah woodland. predominant species are: *Parkia filicoidea* (*dawa-dawa*) and *Butyrospermum parkii* (shea butter), while localy *Acacia albida* is present (IFAD, 1990).

Land use and vegetation comprises mainly compound farming areas, bush fields, pasture, fallow and natural wood savanna woodland (MEYER, 1993). The proportion of fallow has however declined and given way to arable land under permanent or semi-permanent cropping, whereas the broad pattern of vegetation cover has changed very little over the past 20 years (AGYEPONG and KUFOGBE, 1994). Major crops are millet, sorghum and groundnuts followed by maize, bambarra beans, cowpeas and tobacco (IFAD, 1990).

The number of inhabitants in the region in 1989, projected from the 1984 census, was 885,000 of which about 88% was rural. Population densities varied from 37 to 204 per km². This has created an immense pressure on the land, the reason why forested areas have been more or less depleted. Land is held communally with rights granted by the Tindana (earthgod) but landownership itself is vested in the lineage. Average smallholder income is very low and in 1984, 97.5% of the smallholders were expected to live in poverty (i.e. below the Basic Needs Income).

Even though the literacy rate has been improved in the region since the early '60s, only 43% of women and 64% of men in 1985 were able to write. The high illiteracy rate is considered a major hindrance to development programmes in the area (IFAD, 1990).

Methodology

For erosion risk assessment three different levels can be identified: (1) local level assessment with detailed data and analysis which can guide specific management interventions (2) regional analysis for general policy oriented assessment and finally (3) continental or global evaluations representing a more general level of assessment (GRUNBLATT et al., 1992). This study can be placed in the second category where the decision-makers will be bodies within the regional administration including the extension service (Fig. 2) thereby being capable of designing specific programs to handle the situation.

The GIS system will eventually consist of two basic models: the physical erosion risk model and the socioeconomic erosion model consisting of both maps and tabular data. These will together make up the erosion risk assessment model, which can be linked with other information for further modelling.

In the following the various models will be outlined.

Physical erosion risk model

The physical erosion risk model incorporates the same factors as WISCHMEIER and SMITHS (1978) Universal Soil Loss Equation (USLE) being erosivity, erodibility, slope and crop management. The soil management aspect has however been left out since it does not vary much at the regional scale.

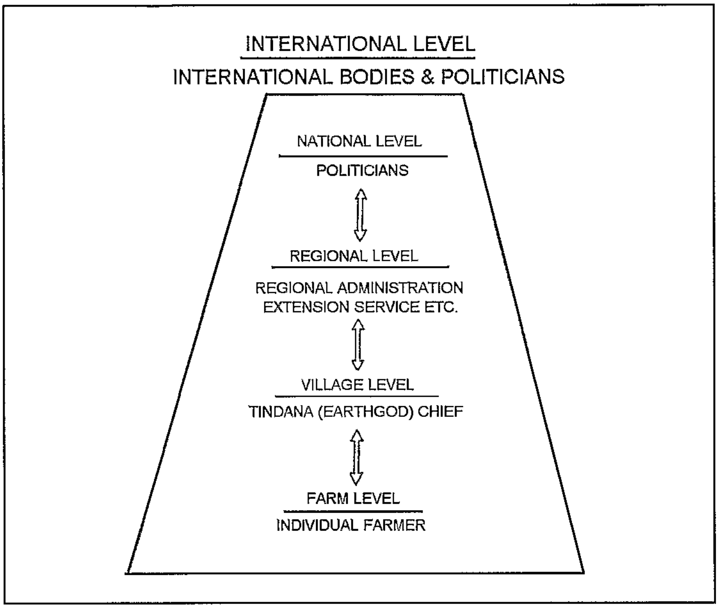

Figure 2. Decision-levels within the studied environment.

Soil loss in t/ha will moreover not be calculated since no calibration of all the parameters have taken place for that sub-region of Africa. A relative erosion risk assessment will instead take place allowing the socioeconomic erosion model to be easily incorporated in the final analysis.

The individual parameters are determined in the following way:

Erosivity

HUDSON's (1989) erosivity index: KE > 25 has been used to determine erosivity in which the assumption is that the intensity of 25 mm per hour can be taken as a practical threshold level separating erosive and non-erosive rain. Erosivity is given as tabular data due to the regional scale.

Erodibility

Existing soil maps based on the FAO-UNESCO soil legend (ASIAMAH, 1992) were used as the basis for the erodibility assessment, which mounted to a relative risk assessment between the different soil types. Within the 10x10 km grid in the study area systematic sampling (SILK, 1979) took place with one kilometer spacing. Erodibility was determined based on the following parameters:

- Organic Matter Content (OMC);
- Aggregate stability (wet-sieving);
- Shear strength;

- Soil strength;
- Soil texture;
- Infiltration;
- Soil profile characteristics.

These parameters were found to be of major importance with respect to erodibility in the region (FOLLY, in press). The establishment of the grid made it possible to decide whether differences between various soil types with respect to erodibility are significant.

The slope factor

Topographical sheets 1:50,000 have been digitized and run through the SEM (Structural Elevation Model) in ARC/INFO which is using Triangular Irregular Networks (TIN) approximating a three dimensional surface through a network of irregularly sized triangles.

Crop management/land use

A land use map has been made based on visual interpretation of texture and colour on satellite imagery, supported by fieldwork carried out in 1990 and 1991 (MEYER, personal communication). Four major classes have been identified where risk of erosion decreases downward (MEYER, 1993):

A: Areas dominated by compounds. Compound fields occupying major parts of the area. The rest consisting of pasture and fallow.

B: Areas with compounds and compound fields making up about half of the area. Mixed with pasture and fallow.

C: Uninhabited areas of bush fields, pasture, fallow mixed with natural vegetation.

D: Natural savanna woodland.

The pattern of land use determines the intensity at which the soil is farmed being directly related to crop management.

The physical erosion risk model is illustrated in figure 3.

Socioeconomic erosion model

The socioeconomic erosion model is assisted by data on socioeconomics and two maps, these being: the population erosion risk map and the vegetation cover map.

Population erosion risk map

Population density map at the scale of 1:2,000,000 has been reclassified with the aid of statistical data on population projected to 1995 and digitized. A field visit including interviewing is going to take place in 1995 to provide for additional data.

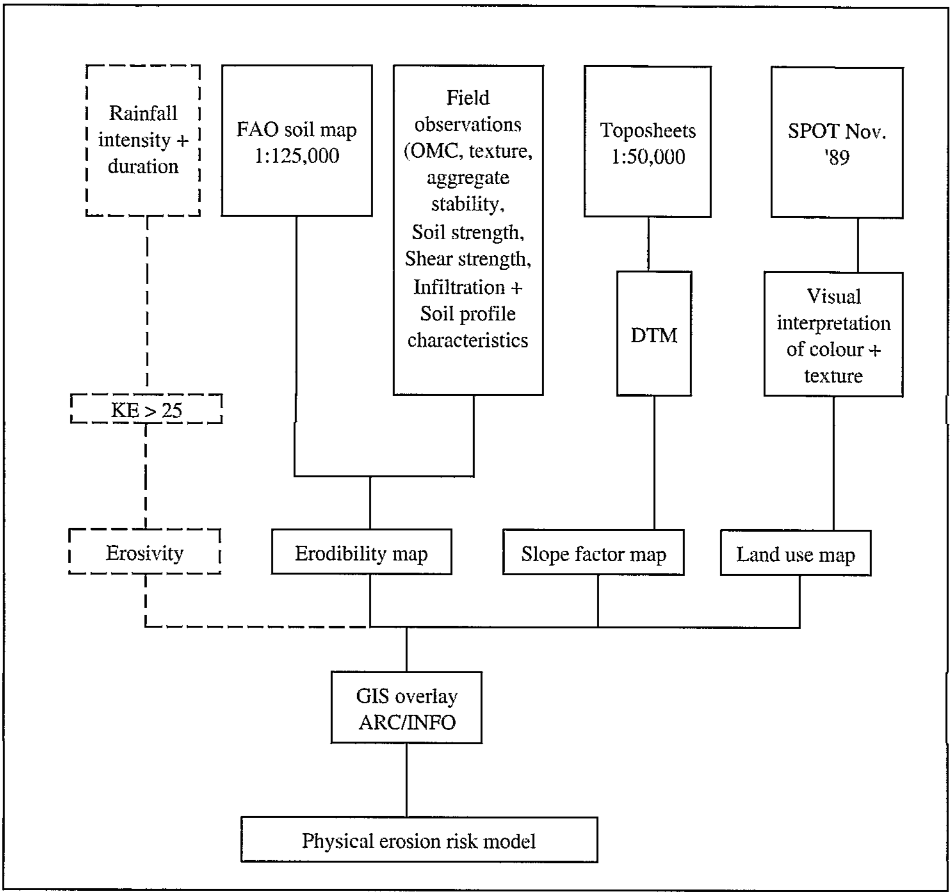

Figure 3. Lay-out of physical erosion risk model.

Vegetation cover map

Landsat TM data of April 1994 are presently being classified using simple box-class classifications of spectral values of bands 5,4 and 3 in a principal component (PC) based system CHIPS (Copenhagen Image Processing System), developed at the Institute of Geography, University of Copenhagen. This is followed by a post-classification visual correction as described by REENBERG (1993b, 1994).

Combined with field data and statistical data on livestock density a vegetation cover map will be made. Additional socioeconomic data such as political consciousness, land tenure and education will be added as tabular data making up the socioeconomic erosion model (Fig. 4).

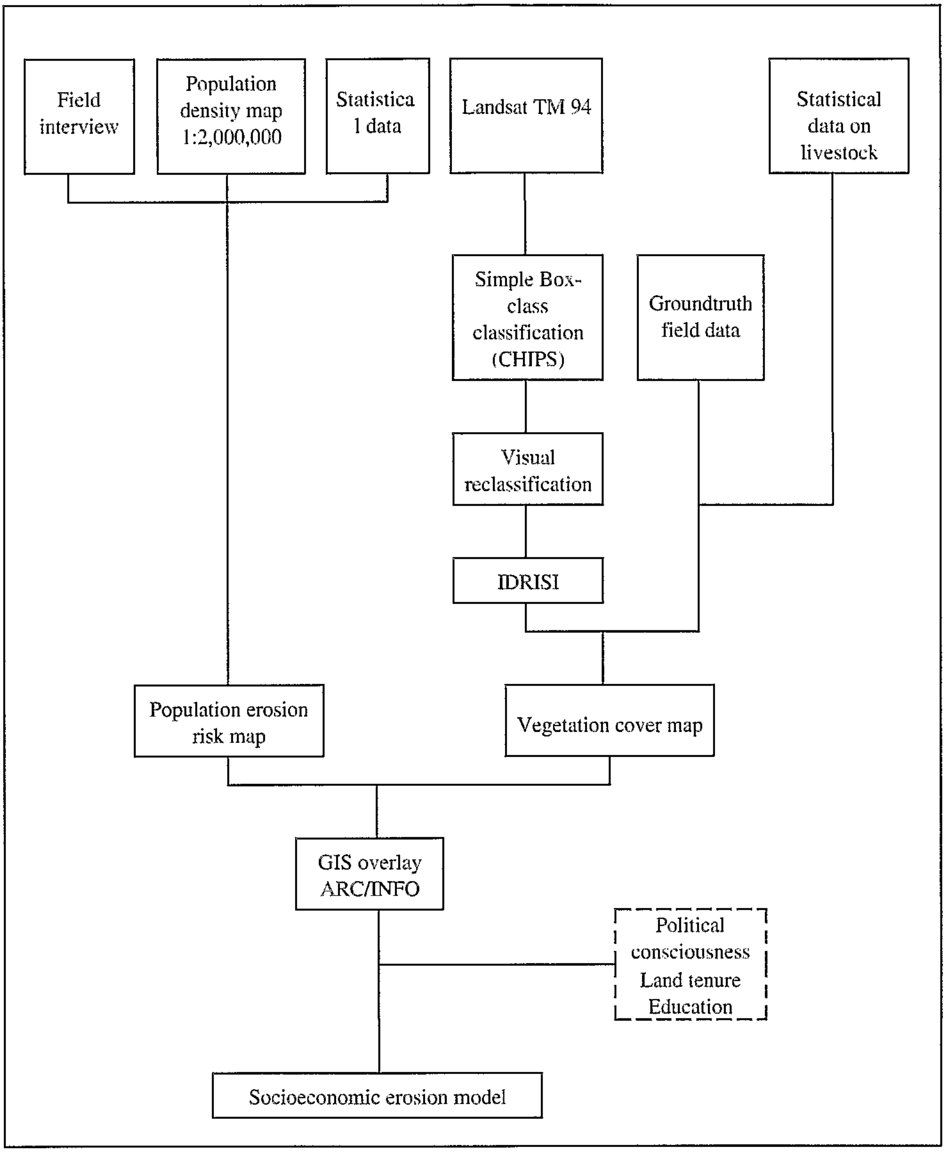

Figure 4. Lay-out of the socioeconomic erosion model.

Discussions/conclusion

The above described models allow to make an erosion risk assessment model. Due to ongoing research final results cannot be presented at the present stage.

The results will be used for further modelling within GIS (Fig. 5) by changing inputs thereby projecting future erosion risk areas in case certain trends continue in the region.

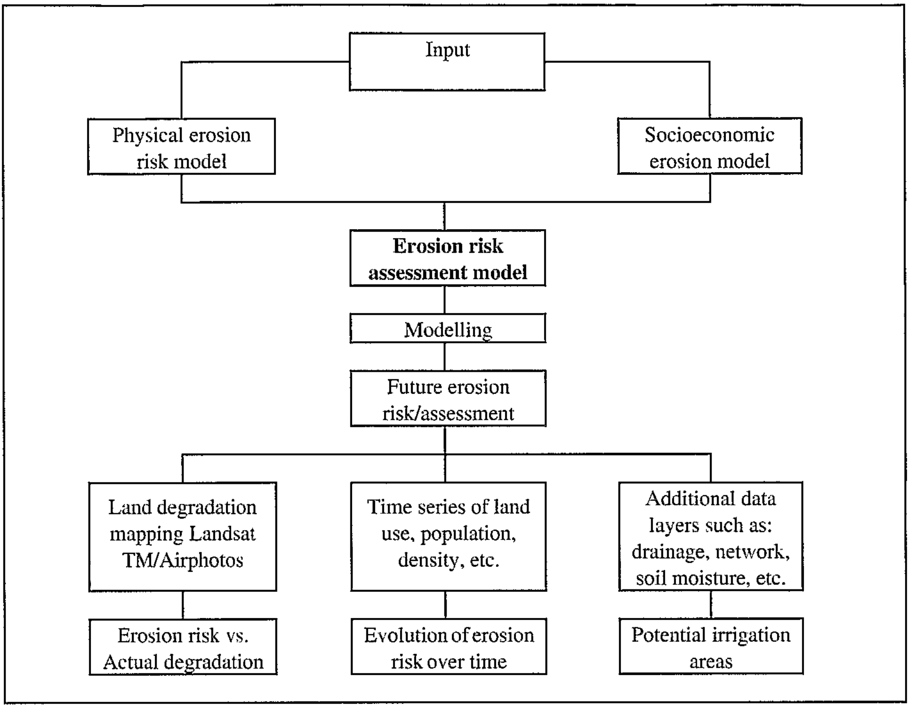

Figure 5. Lay-out of erosion risk assessment model with possible future applications.

Apart from that the described system has a lot of potential users, additional data may be incorporated such as for example present land degradation mapping which can be used to compare the actual situation with the potential situation. Old data can be digitized to assess the evolution of erosion risk over time. And further information on drainage network, soil moisture etc. can be added to plan the lay-out of irrigation sites (TAUER and HUMBORG, 1992).

The present paper seeks to illustrate the usefulness of remote sensing data and relevant available socioeconomic data as a means of obtaining up to date information in developing countries where the data often are rather scarce. The GIS helps in analyzing as well as in projecting future developments within the region.

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