SOIL-EROSION RELATIONSHIPS IN A FORESTED WATERSHED OF SOUTH INDIA.

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RESUMO

A structural approach is used in order to understand the development of natural soil erosion in a forested watershed in South India with a widespread red soil (Rhodic Lixisols) and black soils (Vertisols and Vertic intergrades) cover. The soil map was established from the observation of isolated soil profiles and toposequences, and surveys of soil electromagnetic conductivity, geology and vegetation. The morphology of area vulnerable to erosion was studied along a toposequence, and its hydrological functioning was monitored through neutron probe measurements. Results indicate that both topography and lithology have influenced the distribution of the soils. At the bottom of the watershed, the morphology of the soil cover shows that it has developed in the following order: red soil > black soil > bleached horizon at the top of the black soil > streambed > bleached horizon below the black soil. The development of the streambed is a recent process, which was guided by the presence of thin black soil with a vertic horizon less than 2 m deep. Three types of erosion features have been identified. Type 1 and 2 erosion are located at the intersection between the streambed and the red soil – black soil contact. Two water tables occur in the soil cover: (i) a perched watertable at the top of the black soils after swelling and closing of the cracks and (ii) the other below the black soil in the saprolite of the gneiss due to the oscillations of the water level in the stream. These two temporary watertables provoke the bleaching of two horizons that are fragile and hence favour erosion. The third type of erosion occurred at midslope and at the cross between the stream and the loose sandy saprolite of the gneiss occurring at topsoil. It is related to the evolution of the slope from convex hills to concave pediments, accompanying the regional climatic gradient. The understanding of natural erosion at non-anthropic forested area should help in understanding and managing erosion in cultivated areas around our study site in South India.

Keywords: Erosion, Rhodic Lixisol, Vertisol, South India.

INTRODUCTION

Several studies in India deal with assessment and control of soil erosion, which is a major parameter for sustainable development of agriculture (Patel et al., 2002, Singh et al., 1985; Nisar Ahamed et al., 2000). Although soil loss depends widely on the type of soil, it is usually attributed more frequently to inappropriate land use. A lot of effort has been taken for almost 15 years to estimate the soil erosion in India and particularly on the widespread red soil-black soil system (Babu et al., 1978; Narayana and Babu, 1983; Singh et al., 1992; Seghal and Abrol, 1994). The erosion rate of ‘Red Soils’ (Rhodic Lixisols, FAO-ISRIC-ISSS, 1998) is usually estimated below 5 tonnes/ha/year. In contrast, the erosion rates in the ‘Black Soil’ (Vertisols and Vertic intergrades) of the region is generally about 20 tonnes/ha/year. The limit for sustainable development is usually fixed at about 11 tonnes/ha/year (Wischmeier and Smith, 1978). Although it is today widely known that internal transformation of a soil cover can influence or even govern the landscape evolution through intensification or decrease of erosion processes, the soil cover itself is still considered as a black box in most of the studies on soil erosion. Very little is known about natural erosion in non-anthropic forested areas in South India, because soil loss is usually attributed to anthropic influences such as extensive deforestation and dryland farming system consisting of 5 to 7 months of fallow (Bronger et al., 2000). The aim of this study is to present the main factors intrinsic to the soil cover that govern natural erosion on a non-anthropic forest area with a red and black soil system, using a structural and a spatially distributed approach.

SITE

In South India, the mountains of Western Ghâts form an orographic barrier, inducing an important climatic gradient, with annual rainfall decreasing progressively from about 5000 mm in the west, to less than 750 mm at 80 km eastwards. It is associated with changes in the landscape geomorphology from convex hills intermittent with flat floors to long concave ‘glacis’ (Gunnel and Bourgeon, 1997). In parallel, the soil types range from Oxisol to thin red soils (Rhodic Lixisol) associated with black soils (Vertisol, calcic Vertisol, Vertic intergrades) (Murthy et al., 1982; Jacks and Sharma, 1995; Bourgeon, 1991). Red soils are considered paleosols that formed in an earlier period with a moister climate than the present, whereas the formation of black soils depends mainly on the slow down of the solution and lack of drainage usually in bottom part of the landscape (Bronger and Bruhn, 1989; Subramanian, 1993).

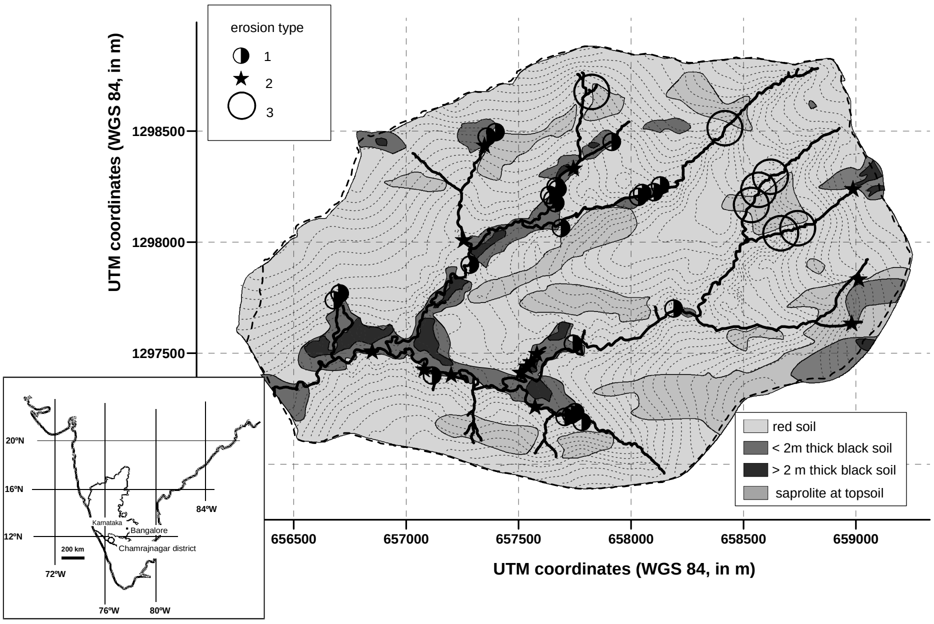

Fig. 1: Soil map of watershed, distribution of erosion and of the studied sequence T1

Fieldwork was carried out on a 4.5 squared km forested watershed (Fig. 1) located in the Bandipur National Park, in the climatic transition area (Karnataka state, Chamrajnagar district). The mean annual rainfall spread over 20 years is 1120 mm mostly distributed from June to September. The mean yearly temperature is around 27ºC. The substratum consists of a gneiss intermingled with amphibolites and quartz dykes. The drainage of Moole Hole watershed is sub-parallel to sub-dendritic. Streams are temporary flowing for a few hours to a few days after the stormy events of the rainy season. The vegetation is a dry deciduous forest.

METHOD

An exhaustive GPS georeferenced survey of the streambeds and the soil erosion pattern was carried out for the entire watershed. The soil map (Fig. 1) was realised through electromagnetic conductivity survey (Barbiero et al., 2004), profiles and sequences observations. An existing representative spoon shaped erosion was taken advantage for the excavation of a 80 m long trench (T1) in order to understand the morphology of the area vulnerable to soil erosion. Five boreholes were drilled down to the saprolite in red soil, black soil and transition area, along a line parallel to T1 and located at 5 m. Soil moisture was monitored during two rainy seasons through neutron probe measurements.

RESULTS AND DISCUSSION

The watershed area is mostly undulating with gently sloping pediments and the elevation of the watershed ranges from 820 to 910 m above sea level. The major part of the watershed is covered by red soils. Thin red soils overlaying loose gneiss saprolite are mainly located on the central dome between the two main streambeds and in a discontinuous crescent shape area along the slopes. Black soils have developed on two types of location: 1. Bottom area occupying the lower part of the slope and the flat valley bottoms; 2. At higher levels into depressions on the crest line.

All the erosion spots are located in the vicinity of the streambeds. The first and the most widespread type is a spoon shaped erosion with vertical edges. These spoon shaped erosions are distributed at the crossing between the streambeds and the red soil-black soil contact. The second type is superficial erosion. It was observed at the top of the black soils and is developed at a textural contrast between a clay horizon and the sandy topsoil. The third type is much wider and develops also in the vicinity of the streambeds but only at places where the loose saprolite of the gneiss is close to the topsoil.

The concordances or discordances between several sectors of the landscape along T1 make it possible to draw the relative chronology in the formation of the soil and development of the streambed (Fig. 2). Five different domains are distinguished, namely the red soil A, the black soil B, a bleached domain C at the top of B, the streambed D, and the bleached domain in the saprolite E. The red soil domain A is developed along the slopes under good drainage conditions, and consists of horizons concordant with the slope topography. B is the black soil domain with horizons concordant to the flat valley bottom and developed under bad drainage conditions. We observed that the morphology of B intersects that of A indicating that B has developed more recently. Downslope, the morphology of B is in its turn intersected by C, which has therefore developed subsequently after B and is induced by a sub-superficial drainage at the top of B.

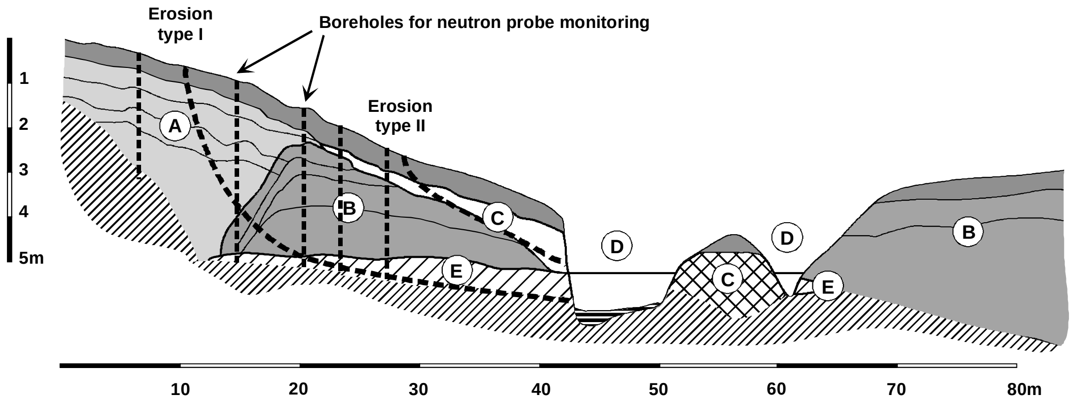

Fig. 2: Cross section along the toposequence T1, showing the morphology of the red soil–black soil system and its relationships with the development of erosion type 1 and 2.

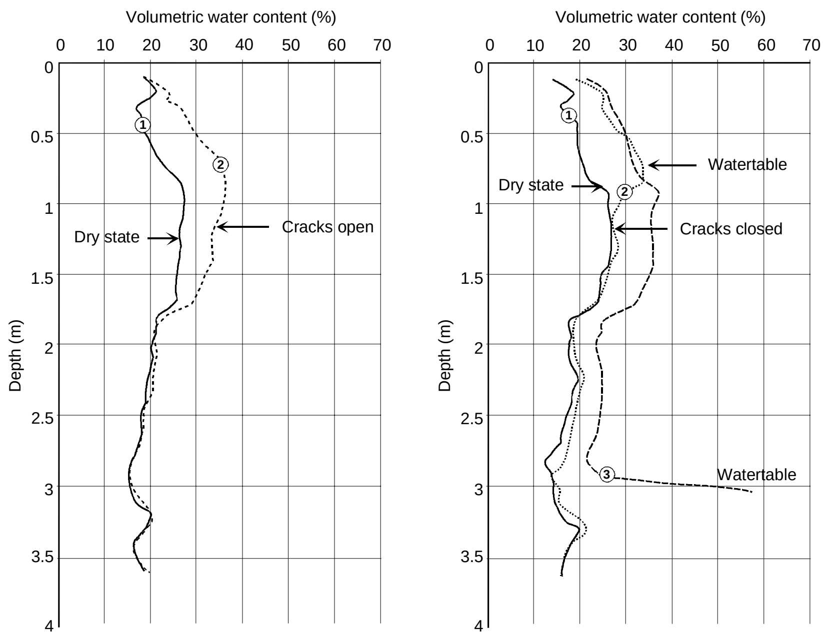

Fig. 3: Neutron probe monitoring in the black soils showing 2 different types of hydrological functioning and the occurrence of the watertables

The fourth domain D is the streambed itself, which is intersecting B and C. The domains B and C were therefore removed by the later development of the streambed. Eventually, the bleached domain E has developed at the base of the black soil and within the saprolite of the gneiss. E is intersecting the red soil-black soil contact A-B. We attribute the bleaching into E to the fast oscillation of the watertable induced by the stream.

Two different types of hydrological functioning were observed in the black soil during the season.

1. At the beginning of the wet season, the cracks of the vertic clay horizon are open, favouring infiltration down to the saprolite after the moisture front reached the vertic horizons.

2. After July, the cracks are closed which significantly decreases the infiltration and results in the formation of a perched watertable in the subsurface within C.

The monitoring along T1 also indicate a substantial but fleeting increase in the moisture content observed below 3 m depth during the floods, which is attributed to a lateral flow from the streambed into the porous bleached domain E. It confirms that the bleaching in this domain can be attributed to a current process.

Erosion types 1 and 2 are occurring close to the contact between red and black soil. The spoon shaped erosion type 1 is provoked by the watertable occurring very fleetly within E. Superficial Erosion type 2 is related to the occurrence of a watertable within domain C at the upper part of the black soil after the swelling and closing of the cracks.

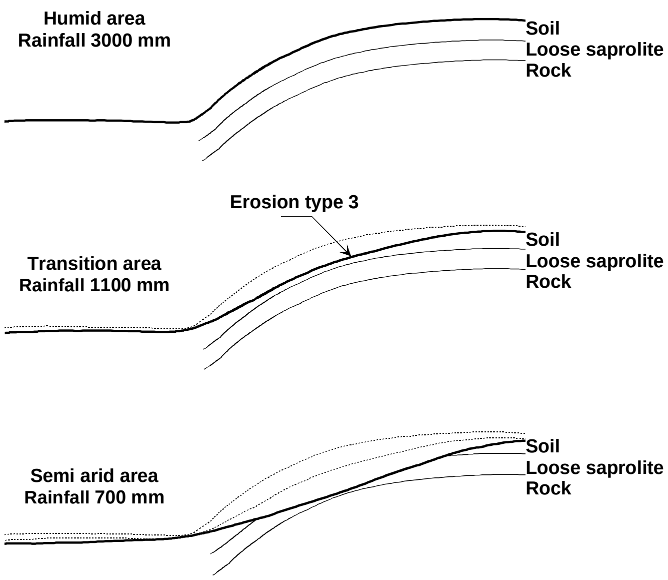

Fig. 4 : Slope shape changes from convex hills to concave glacis accompanying the regional climatic gradient.

The third type of erosion is related to the loose sandy saprolite of the gneiss at place where it appears close to the topsoil, i.e. at the midslope. It could be interpreted in the frame of the slope shape changes (Fig. 4) accompanying the regional climatic gradient (Bourgeon and Gunnell, 1998). The evolution of the landscape geomorphology from convex hills to long concave pediments favoured the occurrence of the rock saprolite at topsoil predominantly at midslope in the climatic transition area. The development of erosion type 3 will in its turn accelerate the change in the slope shape.

CONCLUSION

The objective of this study was to understand the factors intrinsic to the soil cover and likely to influence or even control the development of present and recent natural erosion in the non-anthropic forested area of South India. The issue was tacked through a structural approach, which highlights the relative chronology in the development of the soil cover, and in particular show that the stream development is a recent process. The link between the occurrence, the type of erosion process and the morphology and functioning of the soil cover has been established.

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