

Land use changes and their effects on sediment transport and soil erosion within the Athi drainage basin, Kenya

SHADRACK MULEI KITHIIA

*Department of Geography, College of Education and External Studies, University of Nairobi,
PO Box 30197, Nairobi, Kenya*

Abstract This paper examines the effects of changing trends in land use on soil erosion and sediment transport in the Athi drainage basin, Kenya. The Athi River drains areas that have been subjected to intensive agricultural and industrial activity and population pressure. The resulting intensification of land use has seriously impacted the processes of soil erosion and sediment transport. The climate of this basin varies from tropical rainforest in the upper zones to the more fragile arid and semiarid (savanna type) areas in the downstream zones. Soil type influences soil erosion and sediment transport significantly, with the upper zones exhibiting lower soil erosion rates and sediment loads compared to the middle and lower reaches of the river. This paper documents the trends in soil erosion and sediment transport down the river course. The hydrology of the basin and the land use and soil conservation and management measures employed are examined. In view of the problems resulting from soil erosion and sediment transport, improved land use control and conservation measures are recommended as a basis for achieving sustainable use of Kenya's water and natural resources.

INTRODUCTION

The Athi drainage basin is the second largest drainage basin in Kenya after the Ewaso Nyiro. It occupies a total land area of 132 000 km² representing about 23.7% of the total land area of the country. Evaluation of the effects of land use changes on soil erosion and sediment transport is very important for the basin. This highlights their impacts on the water resources in the basin in terms of water quality degradation and environmental quality in general. Soil erosion rates within the basin has been estimated at 15 and 12 t ha⁻¹ year⁻¹ in the Kajiado and Machakos districts respectively (Tiffen *et al.*, 1994), while the sediment load of the river is over 2 million t year⁻¹ and is projected to increase due to further changes in land use activities. In this paper, both these parameters are discussed in the light of their major impacts on the environment and water resources of the basin and of Kenya in general.

HYDROLOGICAL CHARACTERISTICS OF THE BASIN

The Athi River covers a total drainage area of 70 000 km² and it is periodically subject to floods and droughts. The primary sources of water for the main Athi River originate from the Ondiri springs, the Tigoni falls, the Kikuyu escarpment and the Kabete and Karura forests. Hydrologically, the upper Athi catchment area is drained by the main Athi River with the Koma, Ndarugu, Ruiru, Ruaraka, Mathare,

Mutoine, Mbagathi, Ngong and Nairobi tributaries joining downstream to form the main Athi upstream of its confluence with the Thwake River. Downstream of the Thwake confluence, the river drains large areas characterized by arid and semiarid conditions with predominantly seasonal rivers/ streams and very few perennial streams. The latter include the Tsavo, Tiva and Sabaki rivers which all discharge to the Indian Ocean to the north of the town of Malindi (Kithiia, 1992). The upper areas of the Athi catchment are well drained compared to the middle and lower reaches where the drainage density declines drastically as indicated in Fig. 1. The implication of this is that the upper catchment areas are well endowed with water resources relative to the lower areas. Any land use changes associated with increasing agricultural productivity and with population settlement will have adverse effects on the water resources and subsequently on water quality and the environment in general.

LAND USE CHANGES

Land use patterns within the Athi drainage basin are highly influenced by rainfall patterns, topography and human activity. Agriculture dominates the economy of the upper catchment area (Kiambu district) providing a livelihood to about 70% of the population (Ministry of Planning and National Development, 1994). This changes significantly moving away towards the city (Nairobi) and the southern parts. Within the city industrial activities dominate, while in the middle and lower reaches of the basin livestock and small-scale irrigation are more pronounced.

Land use in the basin can be divided into four general categories, representing agricultural, industrial, livestock grazing and settlements. The use of land by these activities and the progressive downstream changes coupled with climatic variations have had a major impact on soil erosion and sediment transport. The climatic conditions in the basin makes it particularly prone to land and environmental degradation.

TRENDS IN SOIL EROSION AND SEDIMENT TRANSPORT

Soil erosion

Soil erosion problems in Kenya and particularly in the Athi drainage basin date back to the 1930s when it was realized that most parts of the Athi River basin and in particular the Machakos district were experiencing high rates of soil erosion, leaving most potential agricultural land barren (Tiffen *et al.*, 1994). The main factors contributing to this problem were the poor methods of cultivation used at that time, livestock husbandry, and the total lack of soil conservation measures. The government initiated soil conservation programmes, which included terracing, trenching, grass planting and construction of "Gabions" in the late 1930s. These reached a peak in the 1980s and have since achieved important results.

Erosion causes loss of productive topsoil, organic matter, nutrients and water storage capacity. Up to 50% of the annual rainfall can be lost from eroded slopes,

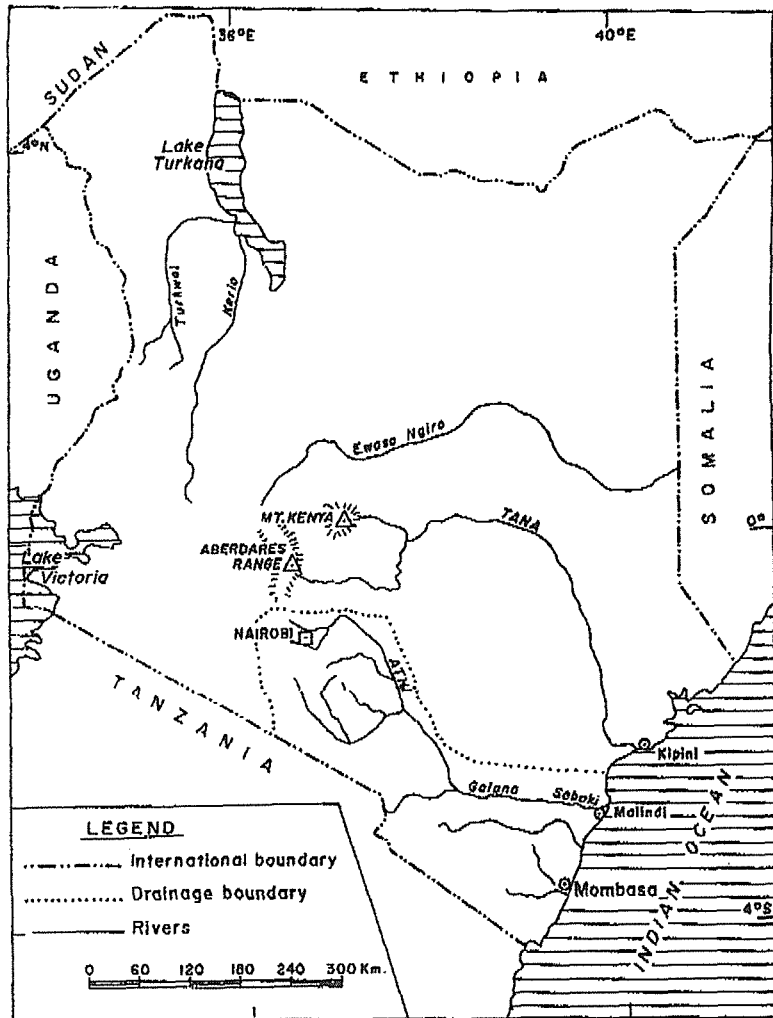


Fig. 1 Athi River drainage basin.

due to decreased infiltration and high surface runoff. The downstream effects of this are increased flood peaks associated with increased sediment loads from the denuded source areas of the rivers. The Athi River experienced major floods in 1961-62, 1968 and 1977 which caused significant damage to property and human life (Ministry of Water Development, 1978). The increasing sediment loads result in faster filling of reservoirs which shortens the useful life of reservoirs along the river.

The application of appropriate and effective soil conservation measures in the basin has reversed the trend of increasing soil erosion and what used to be barren or waste land is now productive and able to sustain better agricultural production for the economic development of the country (Tiffen *et al.*, 1994). The soils are low in organic matter due to the low density of plant life and rapid microbial activity. They also have the added disadvantage of high erodibility due to the poor soil structure which together with low vegetal cover at the beginning of the rainy season and the

high intensity rainfall cause increasing susceptibility to land degradation, mostly in the middle and the lower reaches of the river basin.

Sediment loads

Sediment yield monitoring in Kenya was initiated in 1948 by the Ministry of Water Development (MOWD) and between 1948-1965, the Ministry established a network of sediment monitoring stations in the main water regions of the country. The data collected indicated that by 1985 the area drained by the Athi, Nairobi and, Kiambu tributaries and including Nairobi city, which covered a total area of 510 km² had a total annual sediment yield of 255 000 t. This is equivalent to a specific sediment yield of 109 t km⁻² year⁻¹. Sediment transport in the basin resulting from sheet, rill and gully erosion is greater in the middle and lower reaches of the river.

Sediment load estimates for 1965 and earlier indicate that the Athi basin had an annual sediment yield of 55 000 t, but current estimates have increased to over 2 million. Severe soil erosion results from surface runoff in the Machakos and Kitui districts caused by the destruction of vegetation for charcoal burning, poor cultivation methods and over-grazing (Ongwenyi *et al.*, 1993). These have profound effects on the sediment loads transported by the river.

Table 1 presents the annual suspended sediment loads of the various tributaries from the upper catchment areas through the middle to the lower reaches, sub-divided according to sub-drainage basin codes 3A to 3H in terms of river size. Table 1 shows that the annual suspended sediment load increases progressively downstream in direct proportion to the size of the catchment area and river discharge. This also concurs well with the changes in land use and soil characteristics mentioned earlier in this paper.

SOIL CONSERVATION MEASURES

Soil or land degradation, if left unchecked, can reach disastrous proportions. As noted earlier in this paper, soil erosion in the basin occurs as sheet, rill and gully erosion, which are caused by two natural agents, namely, wind in the dry season and

Table 1 The suspended sediment loads of some tributaries of the Athi River.

Code	River	Catchment area (km ²)	Annual mean discharge (m ³ s ⁻¹)	Suspended sediment load:	
				Mean conc. (ppm)	Annual load (t year ⁻¹)
3AA04	Mbagathi	272	1.6	193	4 456
3BA22	Nairobi	75	1.3	57	2 231
3BB10	Riara	41	0.4	118	1 474
3CB05	Ndarugu	312	4.4	202	29 356
3DA02	Athi at Thwake	5 724	23.6	153	131 089
3F02	Athi at Tsavo	10 272	33.6	549	753 627
3HA12	Athi L. Falls	25 203	33.2	859	2 057 487

Source: Adapted from Ministry of Water Development (1992).

management practices such as:

- (a) continued overstocking resulting in overgrazing of pasture areas;
- (b) indiscriminate slashing, cutting and burning of natural vegetation;
- (c) poor traditional shifting cultivation techniques;
- (d) population pressure which leads to greater areas of land opened up for cultivation.

Thus, any effective soil conservation measures should focus on strategies to reverse or control the conditions promoting accelerated soil erosion. Basically, the prevention of erosion on cultivated land depends on the reduction of soil detachment and runoff velocity whilst on grazing land it depends on the maintenance of adequate vegetative ground cover.

Recommended soil erosion and sediment transport control measures

Measures and strategies which are used for erosion control and soil conservation can reduce the rates of sediment production and transport. The following strategies are recommended:

- (a) designation, construction and maintenance of terraces to control runoff and soil loss;
- (b) use and construction of benches on cultivated land;
- (c) introduction of measures to increase infiltration rates such as increased plant cover;
- (d) use of sediment traps;
- (e) use of rural extension workers trained in the importance of soil and water conservation practices;
- (f) mobilization and participation of rural communities in soil conservation programmes;
- (g) use of demonstration centres such as the ICRAF and KATUMANI Agro-Forestry Centres in Machakos district;
- (h) immediate introduction of regular and standardized sediment monitoring programmes.

In conclusion there is a need for training and support of an increased number of Kenyans in all aspects of water and soil management in related fields such as agriculture, forestry and water management and conservation. It is also emphasized that realistic evaluation of soil erosion and sediment transport must be based upon a thorough understanding of the hydrologic and geomorphic processes as they relate to land use over the entire drainage basin and other similar catchments in Kenya as a whole.

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