CATCHMENT MODELLING FOR PLANNING USE OF LAND AND WATER RESOURCES IN SEMI ARID AREAS

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Abstract

Catchment models provide important planning tools that can be used in management of land and water resources. Models can be used in the understanding of dynamic processes and to predict the rates of these processes thereby providing tools for planning land use. This is very important in semi arid areas where it is difficult to obtain relevant data over a short period such as rainfall, which tends to be irregular and erratic both spatially and temporally.
This paper provides an overview of the problem of soil erosion in Kenya and discusses the relevance of models for planning land water resources particularly for semi arid catchments. Paper to be presented at the Lake Abaya Research Symposium, Hilton Hotel Addis Ababa, 10 – 12 November 2004

Key Words: land resources water resources, semiarid area

1 Introduction

Modelling has enhanced understanding of spatial and temporal aspects in catchments. Indeed it has become possible to make assessment of processes over large areas thus enabling priority management areas to be identified.
An integrated assessment of the land and water resources in semi arid catchments can enable planning for sustainable use of the land, and can be useful in feeding information into general science knowledge as well as in application to the understanding of interactions at the catchment level.

In order to plan the usage of land and water resources in a catchment it is important to assess the biophysical interactions, particularly the land degradation caused by land use change, including effects of farming, deforestation, increasing human population, livestock and wildlife.

2 Erosion and water scarcity

Kenya is a dry region with more than two thirds considered arid and semi arid lands (ASALs). The country has also experienced rapid population growth in the last four decades since independence in the 1960's, resulting in major changes in land occupation and use. These ASALs support more than 50% of livestock and 35% of the population (Langat and Mwangata, 1994, Jaetzold and Schmidt, 1983).

Areas that were previously left to wildlife and pastoralism livelihoods now have been occupied by human settlements from the increasingly densely populated more humid lands. These semi arid areas in the region have now had an increase in subsistence and commercial farming as well as in urbanization.

The manifestations of the changes in human population and level of activity include deforestation as the population encroaches the forests as well as overgrazing as shown in Figures 1 and 2 respectively. The climate in Kenya is also erratic more so in these arid and semi arid areas, making it difficult to monitor the changes due to rainfall directly. Only about 17% of the country has consistently over 600 mm of rainfall annually (Ahn 1979). The issues of concern are therefore increasing soil erosion and land degradation and problems of water scarcity.

Figure 1 Depleted vegetation cover at the edges of Maralal forest

Figure 2 Overgrazing in Baragoi, Samburu

Despite its significance as a component in land degradation, soil erosion has proved almost impossible to estimate over large areas with any degree of precision. Researchers continue in their quest to estimate extent, severity, as well as economic and environmental impacts of soil erosion. This is because it is spatially and temporally highly variable and techniques used such as erosion plots and river yield estimates are point samples that tend to have large errors.
Indeed some long applied techniques of estimating soil erosion have proven unreliable and labour intensive. Yet, the soil erosion rates can provide data to guide decisions about the targeting of funds for mitigation (Batterbury *et al* 2003).

The magnitude of erosion in Kenya varies both temporally and spatially (Table 1) by several studies, with high losses of soil from ASAL catchments. Sediment yield from undisturbed forests catchments is 20 to 30 t km^{-2} yr^{-1} while agricultural basins range between 10 to several thousand t km^{-2} yr^{-1}.
This is depending on the topography, runoff and the proportion of basin that is cultivated (Hai *et al* 2000) in comparison to 1000 t/ha/yr from the semi arid overgrazed and intensively cultivated (Moore 1979).

Table 1 Examples of soil erosion rates in Kenya

Area/ Catchment type	Rates of erosion/ Soil loss	Reference
Semi arid southern Kenya Annual rainfall 700 mm	0.53 – 1.03 cm/year	Wahome 1992
Undisturbed forest catchments Agricultural Land	20 – 30 t/km^2/year 10 – 1000 t/km^2/year	Hai et al 2000
Humid areas Semi arid	0.01 – 0.02 mm/year 0.01mm/year	Dunne et al 1978
Forested highland drainage basins	0.02 –0.03 mm/yr (20-30 t/km^2/yr)	Dunne et al 1981
Semi arid cultivated Overgrazed Recently ploughed Old pasture	40t/ha/yr 109 t/ha/yr 6.1 t/ha/yr 2.4 t/ha/yr	Moore 1978
Forested undisturbed Semi arid lightly grazed Semiarid overgrazed, intensively cultivated	18-26 t/ha/yr 50-140 t/ha/yr 1000 t/ha/yr	Moore 1979
Semi arid	0.2 –10mm/yr	Moore 1983

Generally these studies have shown that the soil characteristics, the vegetation cover and the slope aspects influence the hydrology. Rates also calculated from sediment yield (Dunne *et al* 1979) or using experimental plots (Lewis *et al* 1985, Kilewe 1985, 1987, Omwega 1989, Obando 1990) generally indicate high rates of soil and water losses, particularly from agricultural fields. However, uncertainty still exists on the soil erosion within the semi arid areas, showing the need for further studies.

Soil erosion is only one element of land degradation in these ASALs and is linked to water scarcity. Of the country's total annual rainfall, about 20-30% and in some extreme cases up to 50% is lost through direct surface runoff (Omwega 1989). There is also loss through evaporation estimated at about 40%, thus leaving only 10-20% as infiltration and basin storage. In the ASALs, traditionally hand dug wells (Figure 3) in the seasonal rivers have been in use by the pastoralists for household water and for the livestock.

In addition, knowledge on the amount and distribution of water resources during different seasons has been learned and passed down to pastoralists who know the terrain and resource base.
Construction of boreholes (Figure 4) and sand dams (Figure 5) are increasing being used by development agencies so as to improve water availability. These issues can be better addressed by improved understanding of the involved in erosion processes as well as methods of conserving water in ASAL catchments.

Figure 3 Hand dug well in Baragoi River, Samburu

Figure 4 Covered borehole in Baragoi River, Samburu

Figure 5 Building sandbanks on Baragoi River, Samburu

3 Models for Planning

Planning of land usage and water resources in semi arid areas requires an understanding of the interactive processes. Several models have been developed both at field and catchment scales (Table 2). These models are useful depending on the several factors including the quality of input data. In many circumstances, relative results from models are more reliable than absolute results (Jetten *et al* 1990).

Table 2 Field scale and catchment scale models

Field scale		Reference
CREAMS	Chemicals, runoff and erosion from agricultural management systems	
EPIC	Erosion-productivity impact calculator	Williams et al 1990
EUROSEM	European soil erosion model	Morgan et al 1994
SLEMSA	Soil Loss Estimation Model for Southern Africa	Elwell 1991
USLE	Universal Soil Loss Equation	Wschmeier 1978
Catchment scale		
ANSWERS	Areal non-point source watershed environment management practices fro soil conservation	De Roo 1993
EUROSEM	European soil erosion model	Morgan et al 1994

Modelling is attractive but has shortcomings related to validation. The earliest models were empirical equations based on large database from plot studies in a wide range of environments over many years. The Universal Soil Loss Equation (USLE) was the first generation of erosion model, which was used in planning, and designing soil conservation measures and in assessing the environmental impacts of changes in land use (Wischmeier 1978).

The new generation of models are process based, reflecting the most recent advances in hydrological and erosion research. Process based soil erosion models have become exceedingly important in estimating soil loss. Kirkby (1972) developed the simple Musgrave equation 1947 into a general equation for estimating total potential erosion rate with a variant for rill erosion and a methodology for its used as an erosion indicator. It has been found that erosion declines exponentially as its key controller vegetation cover increases, at 30% cover; the soil erosion is reduced to 30% of its value on bare soil. Several researchers have shown this to be the case (Elwell and Stocking, 1976; Thomas, 1978, Thornes 1987, Obando 1997, Mati et al 2002).

Thus once the threshold for any catchment has been established it becomes possible to plan for use of the land such that the vulnerable areas have permanent vegetation cover. Using the water balance equation, it is possible to plan the areas of the catchment to leave with permanent vegetation, and those that can remain bare without increased losses of water through surface runoff. This can be done to provide for various scenarios, enabling relative values to be used in planning the use of land and water resources.
This is the challenge that now faces researchers working in ASALS in Kenya.

4 Conclusions

Modelling tools can be used in planning of land usage and water in the arid and semi arid lands of Kenya. Erosion rates from various researches have provided information on the severity and variability of erosion and these can now be used as input in simple models that can provide immediate information to decision makers. However one needs to remember that models cannot replace the actual catchment interactions

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