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A tool for rapid assessment of erosion risk to support decision-making and policy development at the Ngenge watershed in Uganda

Fiona P. Mutekanga [a,b,*], Saskia M. Visser [a], L. Stroosnijder [a]

[a] Wageningen University, Soil Science Centre, Land Degradation and Development Group, P.O. Box 47, 6700 AA Wageningen, Netherlands
[b] Kyambogo University, Faculty of Science, P. O. Box 1, Kyambogo, Uganda

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ABSTRACT

This study tests a rapid, user-friendly method for assessing changes in erosion risk, which yields information to aid policy development and decision-making for sustainable natural resources management. There is currently a lack of timely, up-to-date and current information to support policy development on sustainable natural resources management in Uganda. The study was carried out in the Ngenge watershed, a typical catchment in the Ugandan Highlands, characterised by deforestation in favour of subsistence agriculture without adequate soil and water conservation measures. The watershed is experiencing soil erosion, sedimentation and flooding problems which are threatening agricultural productivity and food security. Sustainable management of environmental resources is needed to ensure a livelihood for the rural population which is dependent on the land. Historical erosion risk was evaluated in three steps using multi-temporal satellite data. First, current erosion risk was assessed by combining slope and vegetation cover during periods of high intensity rainfall. The data used for the assessment was obtained from public (free) satellite images. Erosion risk was then linked to land use and finally to the change in vegetation cover over the years 1980–2000. The analysis of erosion risk using rainfall, slope and NDVI (Normalised Difference Vegetative Index) as a proxy for vegetation cover gives an indication of the current erosion risk in the area. The results of historical vegetation cover change analysis indicate an overall increase in areas under erosion risk in the study area from 1980 to 2000. This method of erosion risk mapping provides a quick and straightforward means for identifying priority areas for interventions for soil and water resource management. Considering that resources are limited, the interventions to be appropriate have to be focused mainly on areas affected by degradation.

1. Introduction

In developing countries soil erosion is considered to be a serious threat to agricultural development (Posthumus and Stroosnijder, 2009). Erosion by water following the clearance of the natural vegetation directly reduces agricultural productivity and, as a consequence, reduces food security (Kessler and Stroosnijder, 2006; Okoba et al., 2007; Tamene and Vlek, 2007). In Uganda, 68% of the population depends mainly on subsistence farming for their livelihood (UBOS, 2002). Their agricultural practices are leading to the degradation of the soil and water resources (Isabirye et al., 2008). Soil erosion is the most severe and extensive form of degradation in the country: it and the depletion of soil nutrients are the major contributors to declining productivity and increasing poverty (Tukahirwa, 1988; Nkonya et al., 2004; NEMA, 2007). Most of the eroded soil is conveyed to the rivers, resulting in increased sedimentation which has raised the river beds, causing frequent flooding downstream (DSOER, 2004).

The continuing degradation of the natural resources threatens the very livelihood of the rural population (NEMA, 2007) and creates an urgent need for mitigation measures. Aided by the African Highlands Initiative (AHI) and other development partners, the Government of Uganda is therefore designing and implementing policies and strategies to address poverty, land degradation and declining agricultural productivity. However, this is no simple matter. Policy and decision-making in the context of sustainable development requires rapid, effective and efficient access to and integration of appropriate current information from a wide range of sources and disciplines, including information on land cover dynamics derived from remotely sensed data (Xiuwan, 2002; Kalluri et al., 2003; Sedano et al., 2005). The existing information on the environment and natural resources of the country is inadequate for appropriate policy development (NEAP, 1994). It is too expensive and time-consuming to carry out soil erosion studies for all the arable soils and climatic conditions (Majaliwa, 2005). Moreover, the high spatial variability of

* Corresponding author. Wageningen University, Soil Science Centre, Land Degradation and Development Group, P.O. Box 47, 6700 AA Wageningen, Netherlands. Tel.: +31 627 255246; fax: +31 317 419000.
E-mail address: Fiona.mutekanga@gmail.com (F.P. Mutekanga).

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soil erosion means that in order to plan mitigation measures, sound knowledge is needed on where erosion is occurring (Le Roux et al., 2007; Visser and Jansen, in press).

Although deterministic erosion models that describe processes and quantitative outcomes, can be used to construct maps, a qualitative approach is usually adequate for land use and conservation planning purposes (Vrieling et al., 2002) cited in (Visser and Jansen, in press). For large areas it will be more feasible to construct erosion risk maps rather than to quantify the erosion (Le Roux et al., 2007; Visser and Jansen, in press). Erosion risk is referred to as the relative risk of erosion occurring at a certain location by comparison with other locations in the region mapped (Visser and Jansen, in press). (Vrieling et al., 2006) showed that erosion risk in a watershed can be mapped accurately using information on the steepness of slopes and vegetation cover only.

For effective policy development, the Government of Uganda needs information on the relation between land use and the risk of erosion. Given the data scarcity in the country, the most appropriate way of obtaining policy-relevant data is to perform an erosion risk analysis using remote sensing data and relate it to current and historical land use. As already noted, erosion risk provides information on the relative risk of occurrence of soil erosion at a specific location under a given land use. Analysing the historical land use based on historical vegetation cover change analysis and combining this information with the erosion risk under a specific land use will provide insight into the historical changes that have led to the current situation.

Since 1995 NEMA has taken over the responsibility of the implementation of environmental management in the country. This is achieved through The National Environment Policy. However, NEMA requires current updated information from the districts on the state of the environment. In the face of insufficient resources a methodology as presented in this paper will enable acquisition of timely information on the state of the natural resources for interventions to be planned appropriately.

The research described here was carried out to test a rapid tool for assessing erosion risk and providing current information to aid policy and decision-making in the context of sustainable development in Uganda. For the assessment of current erosion risk and the evaluation of historical erosion risk, the rapid tool was tested on its capacity to provide adequate, timely, low-cost data which can be used for policy development and decision support. The specific objective of the study was to evaluate the history of vegetation cover change and its influence on change in erosion processes in the watershed. A 3-step method was followed, using multi-temporal satellite data. First, current erosion risk was assessed and the results were validated against field data, then, erosion risk was linked to vegetation cover and finally it was linked to historical cover. The research was carried out in the Ngenge watershed, situated on the northern slopes of Mt. Elgon (1°8′N, 34°33′E), in Eastern Uganda.

2. Materials and methods

2.1. Research area

The Ngenge watershed, part of Mt Elgon, like other East African Highland watersheds is characterised by high population pressure, a favourable climate regime and the cultivation of steep slopes without adequate soil and water conservation measures (Semalulu et al., 1999). Clearance of the forest on the slopes and replacement with annual crops is leading to severe erosion of the soils of the area (BIC, 1998; DSOER, 2004). The River Ngenge is one of the main permanent rivers arising from Mt. Elgon (4321 m.a.s.l.). With its extensive montane forest, Mt. Elgon represents a watershed of international importance; it constitutes a major catchment for some of the major rivers that feed the lakes in the Nile River basin. On its mountain slopes, adjacent to the forest (gazetted as Mt. Elgon National Park), live a large rural population whose livelihoods and economic activities are largely dependent on the ecosystem goods and services of the highlands (Muhweezi et al., 2007). The agricultural activities of this highland population are resulting in severe soil erosion with high sediment loads in the rivers in the rainy season.

The Ngenge watershed (665 km^2; Fig. 1) lies between altitudes 1000 m and 3000 m.a.s.l. and is characterised by a cold humid climate upstream and a semi-arid climate downstream. Upstream, the mean annual temperature is 15.6 °C and the mean annual rainfall is 1450 mm, falling mainly from March to November. Rainfall peaks in April and May during the first and main growing season, which is from March to August. The second season, with less rain, is from September to November. In the central zone of the watershed (henceforth referred to as midstream), the climate is less humid and warmer than upstream, with a mean annual temperature of 20.4 °C and the mean annual rainfall 1186 mm. Here too there are two growing seasons: from March to August and September to November. Downstream, there is one rainy season from April to August, which is followed by a hot, dusty and windy dry season. Mean annual temperature is 22.9 °C and the mean annual rainfall is 932 mm (DSOER, 2004) (Fig. 2).

The soils of the Ngenge watershed are derived from volcanic ash agglomerates. Downstream the soils are dominated by clay and clay loams. Midstream, the soils are silt loams in the cliffs overlooking the plains while towards upstream and in the whole upstream area the soils are sandy clay loams (Chenery, 1960). The soils have medium to high fertility and therefore when combined with abundant rainfall the potential for agriculture is high. Agriculture is the primary source of livelihood for the population in the upstream and midstream areas of the watershed. It is characterised by smallholder mixed crop and livestock production: average farm size is 0.8–1.6 ha (Kapchorwa, 2006), which should provide food for an average household of 5 persons. The main crops are maize, Irish potatoes, beans, wheat, barley, vegetables, bananas and coffee. Bananas and coffee are mainly grown in the midstream area, where settlements are well established. Here there are also several farms under woodlots of *Eucalyptus* spp. and *Grevillea* ssp. The animals kept are cattle, goats, sheep, poultry and donkeys. Downstream, the main sources of livelihood are selling fuel wood, burning charcoal and, recently, as a result of increased flooding and sedimentation, growing rice. Agricultural production in the watershed is mainly for subsistence purposes; any surplus is sold. Fertilisers and manure are applied to improve yields upstream and midstream, but downstream no inputs are required because the soil is enriched by sedimentation after flooding. Ox-ploughs, donkeys and human labour are used on the farms. Generally no soil conservation measures are carried out; though in the midstream area, some bunds are constructed and planted with *Napier* grass. However the soil conservation measures in the midstream area do not cover the whole area.

Administratively, the Ngenge watershed lies within Kapchorwa District, and is situated about 12 km east of the main town, Kapchorwa. The watershed encompasses five subcounty areas which adequately correspond to the three main sections of the watershed: Benet and Kwosir upstream, Binyiny and Kaproron midstream, and Ngenge in the floodplain. The total population in the watershed is 55,068 and the population density 262 persons km^{-2} (UBOS, 2002). The average annual population growth rate between 1980 and 1991 was 2.2% and between 1991 and 2002 it increased to 3.5% (UBOS, 2002). The greater part of this population is concentrated upstream (average pop density: 422), followed by the midstream area (average pop density: 297). Downstream the population density is very low (average value: 9). The reason the population density is low downstream is because people have left the area, fleeing the insecurity brought about by cattle rustlers. The very high population density upstream is due to resettlement of the forest dwellers, as well as to settlement of people from the plains and those coming to exploit the soil resources for agriculture. The resettlement of the forest dwellers as well as other landless people