Available online at www.sciencedirect.com
ScienceDirect
Land Use Policy 24 (2007) 129–140
Land Use Policy
www.elsevier.com/locate/landusepol

Land use changes and hydrological impacts related to up-scaling of rainwater harvesting and management in upper Ewaso Ng'iro river basin, Kenya

Stephen N. Ngigi[a,b,*], Hubert H.G. Savenije[b,c], Francis N. Gichuki[a,d]

[a]*Department of Environmental and Biosystems Engineering, University of Nairobi, P.O. Box 29053, Nairobi, Kenya*
[b]*Institute for Water Education (UNESCO-IHE), P.O. Box 3015, 2601 DA Delft, The Netherlands*
[c]*Delft University of Technology, P.O. Box 5048, 2600GA Delft, The Netherlands*
[d]*International Water Management Institute (IWMI), P.O. Box 2075, Colombo, Sri Lanka*

Received 26 November 2004; received in revised form 22 October 2005; accepted 28 October 2005

Abstract

Some land use changes are driven by the need to improve agricultural production and livelihoods. Rainwater harvesting and management is one such change. It aims to retain additional runoff on agricultural lands for productive uses. This may reduce river flows for downstream users and lead to negative hydrological, socio-economic and environmental impacts in a river basin. On the other hand, rainwater storage systems may lead to positive impacts by reducing water abstractions for irrigation during dry periods. This paper presents a conceptual framework for assessing the impacts of land use changes in the upper Ewaso Ng'iro river basin in Kenya. It is based on a people–water–ecosystem nexus and presents the key issues, their interactions and how they can be addressed. The paper presents hydrological assessment of up-scaling rainwater harvesting (HASR) conceptual framework, which assesses the impacts of land use changes on hydrological regime in a river basin. The results will enhance formulation of sustainable land and water resources management policies and strategies for water-scarce river basins.

Keywords: Hydrological impacts; Conceptual framework; Rainwater management; Water abstraction; Integrated water resources management; Land use policy

Introduction

Population growth-induced agricultural intensification is taking place at an unprecedented rate in parts of Ewaso Ng'iro river basin. In semi-arid environment, where water is a major constraint to agricultural production, rainwater harvesting and management (RHM) systems are increasing in popularity (Ngigi, 2003a). The water retained by rainwater harvesting systems is part of the surface water that drains to lower reaches of the river to meet downstream water requirements. Sustainable agricultural intensification dependent on RHM requires that we address the following questions (i) How much water can be retained by RHM systems without adversely affecting the hydrologic regime, socio-economic and environmental conditions further downstream? (ii) How much would RHM systems reduce dry season irrigation demands and river water abstractions? and (iii) What proportion of the water retained in the catchment by RHM systems is used to recharge groundwater resources and sustain dry season river flows? The challenge is to identify appropriate responses to the threats of human activities on natural hydrological and ecological regimes in river basins (IAHS, 2003).

There is growing consensus for a need to improve agricultural productivity and water resources management to meet new challenges posed by increasing demand and diminishing water supply. However, the options, processes and impacts of desired change are less clear (Hajkowicz et al., 2003). Thus stakeholders are searching for a conceptual framework that can integrate policy, water users' aspirations and strategic actions to achieve the

*Corresponding author. Tel./fax: +254 20 2710657.
E-mail address: gharp@wananchi.com (S.N. Ngigi).

0264-8377/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.landusepol.2005.10.002

desired change. Hoekstra (1998) stated that the problem in integrated water resources assessment is not a lack of appropriate tools in any of the related sectors, but rather the lack of integration of these tools and the difficulty of translating analytical results into policy-relevant information. We need to support this statement by highlighting (i) the available tools, (ii) lack of integration of these tools, and (iii) difficulties in translating results into policy-relevant information. To address the most policy and management issues as perceived by users under different biophysical and socio-economic environments and taking into account needs for sustainable development, water-related physical (hydrological, climatological, ecological) and non-physical (technical, sociological, economics, administrative, law) observations are a prerequisite (UNESCO, 2005).

In an attempt to address this, conceptual framework for assessing hydrological impacts of up-scaling RHM in a river basin was developed. Up-scaling here refers to both moving from smaller to larger or improved systems (vertical up-scaling) and replication of the same systems (horizontal up-scaling or scaling out, i.e. increased adoption). The conceptual framework can be used to investigate hydrological, socio-economic and environmental impacts of intensifying agricultural production. However, the main focus is hydrological impacts related to up-scaling of RHM systems and increasing water abstraction for irrigation. The case of Naro Moru river sub-basin is used to highlight the impacts of land use change on river flows.

Description of the study area

Background information

This section presents the background of Ewaso Ng'iro river basin, anticipated land use changes, persistent water crises, opportunities and constraints, hydrological processes and production systems. The upper Ewaso Ng'iro basin, which constitutes a drainage area of 15,251 km^2, is part of the Juba basin, which covers parts of Kenya, Ethiopia and Somalia (see Fig. 1). It is situated between latitudes 0°20′ south and 1°15′ north and longitudes 35°10′ and 38°00′ east. It drains from Rift Valley escarpment to the west, Nyandarua ranges to the southwest, Mt. Kenya to the south, Nyambene hills to the east, Mathews range to the north while the downstream outlet lies at Archer's Post.

The topography of the basin is dominated by Mt. Kenya, Nyandarua ranges and Nyambene hills. Altitude ranges from 862 m at Archer's Post to about 5200 m at the peak of Mt. Kenya. The river basin is divided into three zones based on topography: mountain slopes, lower highlands and lowlands. The mountain slope is the forest zone of Mt. Kenya and Nyandarua ranges. In the upper mountain slopes elevations range from 2500 to 4000 m. The extensive gently undulating Laikipia plateau at an elevation of 1700–1800 m occupies most of the central region. The lower highlands constitute the area adjacent to the lower mountain slopes and the immediate Laikipia plateau between 1800 and 2100 m. The lowlands to the north and northeast have elevations ranging from 1000 to 1700 m.

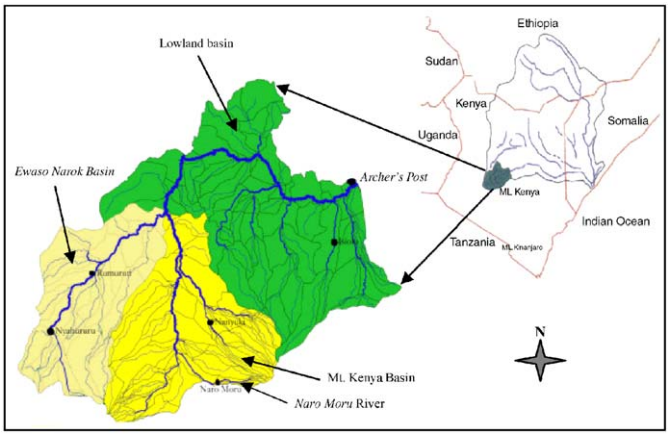

Fig. 1. Location and main sub-basins of the Ewaso Ng'iro river basin.

The river basin has diverse soil types, which include stony *mollic Cambisols* and *mollic Andosols* of medium depth, deep *mollic Andosols,* deep *humic Alisols,* volcanic *Phonolites,* well drained, deep, dark red to dark brown friable clay (*Luvisols* and *Phaeozems*), imperfectly drained, deep grey to black firm clay (*Vertisols* and *Planosols*) (Mbuvi and Kironchi, 1994).

The elevation gradient, which determines the rainfall pattern, gives rise to various climatic zones ranging from humid to arid. Long-term rainfall analysis shows high spatial and temporal variation ranging from 300 to 2000 mm yr^{-1}, with a mean of about 700 mm yr^{-1}. The rainfall pattern indicates a recurrence of wet-dry cycles of 5–8 yr (Gichuki, 2002). Rainfall variation affects river discharge, which since 1960 has varied from 0 to 1627 m^3 s^{-1} at Archers' Post. Rainfall intensities are usually high averaging about 20–40 mm hr^{-1} while higher intensity storms of up to 96 mm hr^{-1} have been recorded (Liniger, 1991). There are three main rainfall seasons, namely long rains (March–June), continental rains (July–-September), short rains (October–December). The long rains and short rains contribute 30–40% and 50–60% of annual rainfall, respectively. The average temperature range from 10 °C to 24 °C. The mean potential evaporation ranges from 2000 to 2500 mm yr^{-1}. However, despite the relatively high rainfall, its poor distribution and high potential evaporation affect crop production in most parts of the basin. Water deficit increases drastically with distance from Mt. Kenya (see Fig. 2).

The elevation gradient also gives rise to different climatic and ecological zones, from humid moorlands and forests on the slopes to arid acacia bushland in the lowlands, with a diverse pattern of land use (Decurtins, 1992). Natural resources are under pressure due to dynamic land use changes, migrating farmers, inappropriate land management practices, agricultural intensification and marginalization of pastoral community resulting in resource