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Original Research Article

Ecohydrological tools for the preservation and enhancement of ecosystem services in the Naivasha Basin, Kenya

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ABSTRACT

Applying ecohydrological principles to catchment management provides an opportunity for two distinct, but complementary, strategies: a basis for the interpretation of ecosystem health and a guide for the selection of ecohydrological tools for catchment management. The latter include a number of biotechnologies that can support the sustainability of key ecosystem services effectively.

Lake Naivasha has been an economic development hub of Kenya since pre-colonial times. Now it is dominated by geothermal power production, horticulture and floriculture, hotel and hospitality, small and medium enterprises around the lake, together with intensive smallholder cultivations and pasture in the catchment. Natural resources in the basin have continually attracted diverse local and foreign investments. Advancement in technologies, together with a rapid rise in human population, have exacerbated pressure upon the basin's natural capital. Conflicts between interest groups have often erupted due to fluctuations in water availability and limitations of access to private land. Flower growers, pastoralists, fisher-folk, hoteliers, upper catchment and lower catchment communities often accuse one another of engaging in malpractices over resource use.

These conflicts have more recently resulted in partnerships in resource management however, which have helped in the implementation of research-informed mitigation measures. The most important is the formation of an "umbrella" organisation, Imarisha Naivasha, a quasi-government body set up to catalyse sustainability moves. It sought to achieve this with a Sustainable Development Action Plan (SDAP; 2012–17) and, with funding mainly from the Dutch government, an Integrated Water Resource Allocation Plan (IWRAP), for catchment-wide use of surface and ground waters. On smaller scales,

1. Introduction

Ecohydrology underlines the mutual links existing between hydrological flows and ecosystem functioning, mediated via processes that occur through both aquatic and terrestrial vegetation, defined by its three fundamental hypotheses (Table 1). Changes to discharge and to water quality cause process changes in receiving ecosystems and impacts on vegetation within the catchment (Hypothesis

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successful case studies have demonstrated practical ways forward – a Payment of Ecosystem Services (PES) programme in one sub-catchment has reduced upper catchment erosion; restoration of small dams in another has provided more reliable and cleaner rural water, flood retention and enhanced biodiversity; around the lake, promotion of artificial wetlands that now treat effluent waters from about half the horticultural enterprises.

Recently, proposed new "mega-projects" by both the National, and the Nakuru County governments have brought uncertainty upon the future state of the lake and its catchment. Plans to develop an industrial park and an inland container port for the new Kenyan Standard Gauge Railway from Mombasa to Naivasha, together with the proposal to develop and market Naivasha further as an ecotourism and conferencing destination, have enhanced speculation on investment opportunities and demographic trends, attracting new investors and jobseekers.

Within the framework of ecohydrology, we summarise proposed developments and the management challenges they pose and provide examples of ecohydrological tools recommended to contain the negative impacts on fundamental ecosystem processes. We review the probability of the successful application of such tools.

1). At the same time, through their active role within the water cycle, plants regulate hydrology, by (a) evapotranspiration (returning flow to the atmosphere), which impacts on discharge; (b) water infiltration, which affects runoff time response, and (c) water purification, which enhances the chemical quality of runoff (Hypothesis 2). Finally, the regulatory activities of plants can be enhanced by practical management to benefit the human population (e.g. through environmental flows), so as to achieve sustainable development without compromising the ecological functioning of aquatic systems (Hypothesis 3). The implementation of Ecohydrology thus offers a double opportunity as – (i) it provides a strategy for the assessment of modifications to the water cycle and of their likely consequences; (ii) it guides the selection of biotechnologies for integrated river basin management (Table 2).

The scale of application of ecohydrological principles and practices is broad and it goes beyond single water bodies, to encompass interactions that take place within whole catchments (Zalewski, 2000; Zalewski et al., 2008). At catchment scale, beneficial human alterations to the natural land cover influence large-scale hydrological cycles with positive repercussions onto local climate, biodiversity and people's health, which can be achieved using ecohydrological tools. Examples are in-stream wetlands for river discharge control and for water quality enhancement, riparian zone restoration for enhanced water infiltration and protection of streamwater quality from allochthonous pollution, reforestation on steep slopes to prevent soil erosion leading to water body siltation. Restoring catchment ecohydrology will improve essential ecosystem services for the benefit of human societies (MA, 2005). These are particularly provisional services measured in terms of quantities produced per hectare per year, cultural services measured in terms of the cultural and social development of human communities, and regulatory services that govern the durability of ecosystem processes, without which the concept of sustainability itself would lose any practical meaning (de Groot et al., 2002).

This paper offers an overview of human activities that put the Lake Naivasha Basin under stress, describes tools that have been shown to be promising for counteracting degradation and provides an update of the current state of management proposals. We conclude by discussing the probability of management success, in an ecohydrological context. By providing a focus for assessment as well as a strategy to design solutions, ecohydrology can drive resource use planning for the resilience of ecosystems and for the balanced development of local communities.

Table 1
The fundamental tenets of ecohydrology.

Hypothesis 1: Hydrology regulates biota in aquatic systems
Hypothesis 2: The biota can be manipulated to regulate hydrological processes (including hydrochemistry and geomorphology)
Hypothesis 3: The use of scientific knowledge of this dual relationship between hydrology and biota (the first two hypotheses) can achieve sustainable management of water resources

Source: Harper et al. (2016).

Table 2
Lake Naivasha hydrology.

Latitude	$0^\circ 09'$ to $0^\circ 55'$ S
Longitude	$36^\circ 09'$ to $36^\circ 24'$ E
Altitude	1888 m a.s.l.
Min monthly temperature range	2–12 °C
Max monthly temperature range	20–32 °C
Precipitation at the lake shore	670 mm $year^{-1}$
Precipitation in the upper catchment (3150 m)	1370 mm $year^{-1}$
Evaporation from lake surface	1320 mm $year^{-1}$
Rate of apparent lake level decline over the last 50 years	0.06 m $year^{-1}$

2. Ecohydrological characteristics of the Naivasha catchment

2.1. Hydrology

A string of tectonic lakes have developed along the eastern branch of the Great Rift Valley in Kenya, as a consequence of the tectonic activities that have formed the valley over the past 25 million years. Naivasha is the Rift

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