Environmental flow assessment taking into account the value of ecosystem services, Pangani River Basin, Tanzania

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Mainly based on: PBWO/IUCN 2009 and Turpie et al. 2005

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Key Message: In the Pangani River Basin in Tanzania water is extremely scarce and not all aspirations for the basin in terms of agricultural and energy production can be met. Environmental flow assessment and economic analysis of ecosystem services was used in order to explore strategies for improving the management of the river basin.

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Situation

In East Africa the Pangani River Basin covers 44,000 square kilometres and is home to about 2.6 million people. The Pangani River rises as a series of small streams on the southern sides Mt. Kilimanjaro and Mt. Meru and passes through the arid Masai Steppe before reaching the estuary and Indian Ocean at the coastal town of Pangani. Along its 500 km long course the Pangani River is a lifeline for biodiversity, people and industry, and provides ecosystem services that are fundamental for the economic development of the region. The river is a source of drinking water for people and livestock and supports irrigation agriculture which represents the largest water use in the basin. The Nyumbaya Mungu Reservoir in the upper basin is used for the generation of hydropower (capacity of 8 MW) and is also an important source for fish offering employment in fishery. At the coast, the Pangani Hydropower Station has a capacity of 68 MW, which is vital for industry and economy in the town of Pangani and along the coast. All together the dams of the Pangani Basin provide 17% of Tanzania's electric power capacity (Turpie et al. 2005).

The principal legislation governing water resources in Tanzania is the Water Resources Management Act 2009 (WRM Act) that provides for implementation of the National Water Policy 2002. The WRM Act provides for the legal and institutional framework for river basin management as envisaged by the policy and provides for three levels of basin management: national, basin, and catchment. Local government authorities and community based organizations or water associations are key players in some of these institutions and the minister may delegate some functions to these entities. The Pangani River Basin Management Project (PRBMP) is generating technical information and developing participatory forums to strengthen Integrated Water Resources Management in the Pangani Basin. The project is supporting the implementation of the WRM Act (IUCN, 2009).

What is the problem?

Population growth and the intensification of land use lead to an over-exploitation of water resources and increase the demand and competition for water among land users, industry and ecosystems. Water shortage increases people's vulnerability to droughts and augments poverty as their livelihoods are strongly dependent on irrigation agriculture and fisheries. Industries, in particular hydropower generation, are negatively impacted by water shortage which hampers economic development. Ecosystems like wetlands, riverine forests and mangroves need a minimum flow of water in order to provide wildlife products including fish, plants for medicinal use, reed, timber, fruits and other products which are of great importance for the livelihood of rural population.

The degradation and loss of forests and wetlands increases water stress as these ecosystems contribute to the regulation of the hydrology of the river basin. They retain water during periods with rainfall and release it gradually, which mitigates floods and helps to sustain water flow during the dry season. Wetlands also purify water and control pollution which is important for people's health and industries.

The increasing water scarcity is also a source of conflict. Small-scale users in villages often compete against larger and more powerful claims by industries. Downstream users like cities, industries and hydropower companies are negatively affected by upstream land users like farmers who reduce the availability and quality of water. These conflicts are expected to increase in the future as population is growing and climate change is projected to aggravate water stress.

What was done to solve it? Which ecosystem services were considered and how?

Protected areas in the upper basin at Mt. Kilimanjaro and Mt. Meru play an important role in conserving forests and wetlands, which benefits water provision and erosion control for downstream users. But they are not enough for maintaining water flow and the multiple ecosystem services for the entire basin.

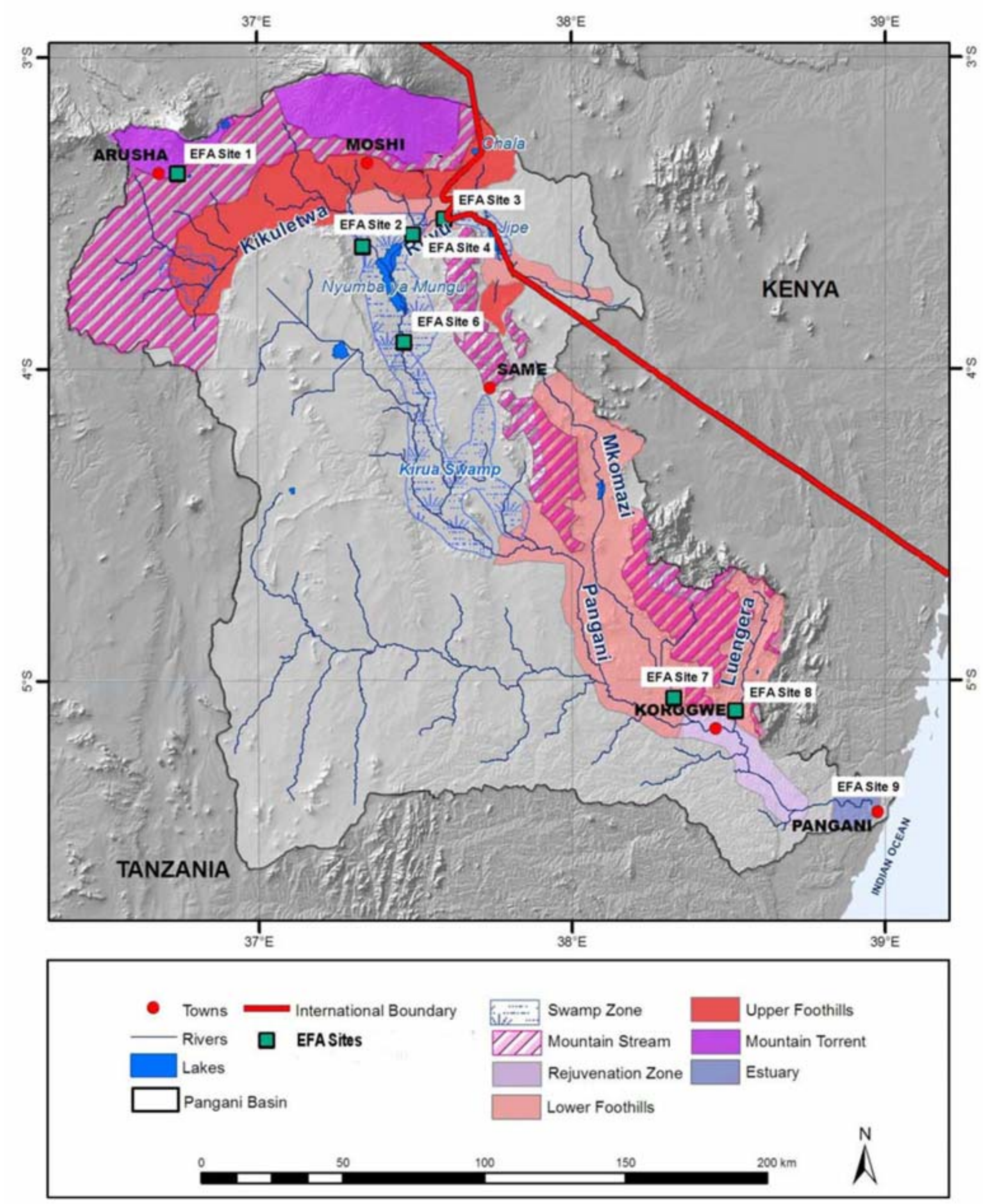
In order to meet the increasing demand for water, conserve ecosystems and their services and for resolving conflicts, a strategy for the sustainable management of water resources, forests and wetlands across the entire Pangani River Basin is required. This does not only include more water efficient irrigation practices and technology but also a water allocation plan that takes into account the demand by all stakeholders in the Pangani Basin including the demand by natural ecosystems.

First pilot projects were developed by IUCN in 2002. Following this the Government of Tanzania, IUCN through its Water & Nature Initiative (WANI), and the Global Environmental Facility (GEF) through UNDP initiated the Pangani River Basin Management Project (PRBMP). The PRBMP is generating technical information and is developing participatory forums to strengthen Integrated Water Resources Management in the Pangani Basin. The aim of the project is to provide information to the Tanzanian government on the costs and benefits of different water-resource management strategies. This information will be used to guide decisions on a fair balance between water development on the one hand and protection of the river and its ecosystems on the other. From 2002 to 2010 the total budget amounts to around US$ 4.78 million.

An Integrated Environmental Flow Assessment (EFA) has been undertaken with the Pangani Basin Water Board (PBWB) as part of the PRBMP, to develop an understanding of the hydrology of the river basin, the flow-related nature and functioning of the river ecosystem and the links between the ecosystem and the social and economic values of the river's resources (Map 1).

The objectives of the EFA were to:

- generate baseline data on the condition of rivers, wetlands and the estuary against which the impact of water-related decision-making can be monitored in the future;
- enhance the understanding among PBWB and Ministry of Water and Irrigation (MoWI) staff of the relationship between water flow, health of the river basin's ecosystems and people's livelihood;
- create awareness of the trade-offs between water development and natural-resource protection;
- develop simple tools to help guide water-resource management and water allocation;
- build capacity that enables PBWB to act as a nucleus of expertise for related work in other areas;
- support the National Water Policy (NAWAPO 2002) and the National Environmental Management Act (2004).



Map 1: Study area with Flow Assessment sites in the Pangani River Basisn (Source: (PBWO/IUCN 2009).

A detailed 18-month planning phase engaged EFA experts to help design a methodology suitable to the needs of the Pangani Basin and to generated information for the PBWB to use in decision making. This included: a hydrological assessment; a health assessment of the rivers and estuary; a socio-economic assessment to describe people's relationship to water and river resources (see example in Table 1); specialist studies on hydraulics, hydropower operations, riparian vegetation, fisheries and invertebrates, macro-economic and climate change; and the development of a decision support system (DSS) tool.

Table 1: Overall average value per household per year derived from harvesting of aquatic resources (including value added in processing). Values are averaged across user and non-user households and given in US$ (converted from Tanzanian shilling (Tsh) using a conversion rate from 2005 of US$ 1 = 1162.79 Tsh). Source: adapted from Turpie et al. 2005.

Products and Services from Ecosystems	Highlands	Upper Basin	Kirua Swamp	Pangani Estuary
Food, Medicinal Plants	**0.05**	**0.70**	**2.05**	**0.15**
Reeds, sedges, grasses	**1.82**	**2.09**	**2.45**	**0.00**
Palms		**3.67**	**3.81**	**74.58**
Mangroves				**6.79**
Reptiles, mammals, birds		**0.01**	**0.01**	
Fisheries		**0.34**	**29.14**	**595.99**
Average total income per household	**1.88**	**6.81**	**37.46**	**677.50**

The information from the EFA was used to organise ecological, social and economic knowledge of the basin to aid future planning and management of its water resources. Possible pathways from 2005/2006 until 2025 were explored by developing different scenarios (PBWO/IUCN 2009). Regulating ecosystem services that are considered important in the Pangani Basin are water treatment by wetlands, and the estuary function as a nursery area for fish. Provisioning ecosystem services by the river and forests such as the provision of fish and timber are described as natural resources (Table 2, PBWO/IUCN 2009).

All scenarios assumed that water demand would increase in urban areas and that water use efficiency in irrigation agriculture would be enhanced by 30% in 2025. Prioritising water allocation to maximise agriculture (Max Agric, Scenario 1 in Figure 1) leads to a gain in agricultural income, but at the expense of hydropower production (HEP) and ecosystem services, with an overall loss in economic output from the basin. Maximising agriculture was predicted to lead to a reduction in ecological health of most parts in the basin leading also to economic losses and in some areas a slight reduction in social well-being (Scenario 1). Maximising hydropower generation (Max HEP, Scenario 2) would improve the basin's economy (Table 2) but cause a reduction in social well-being due to reduced income from agriculture (Figure 1) (PBWO/IUCN 2009).

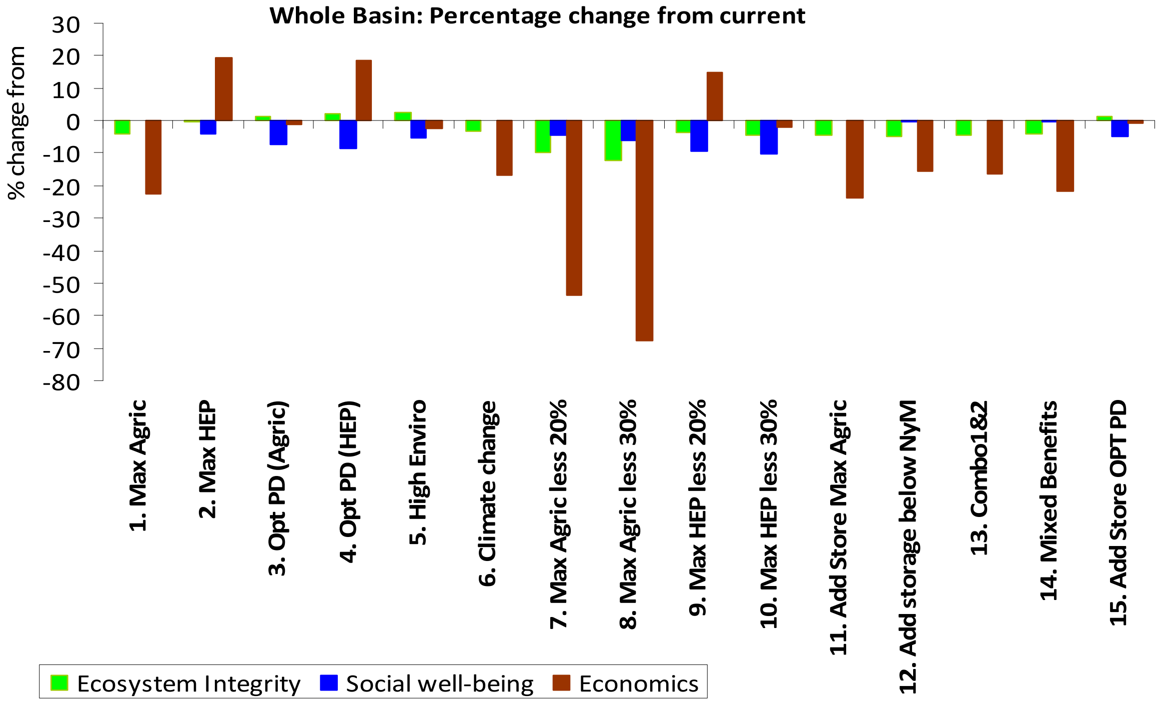


Figure 1: Analysis of different scenarios for the management of the Pangani River Basin. Source: PBWO/IUCN (2009)

Scenarios that do not maximise water allocation for agriculture lead to losses in agricultural production, but where hydropower production (HEP) is high the overall basin-wide economic gains are significant (Scenario 4 and 9, Figure 1 and Table 2). Scenarios that focus on optimising flow patterns (Optimise Present-Day flows (Opt PD), Scenario 3, 4 and 15), or that maximise river health (High Enviro, Scenario 5), lead to the greatest improvements in ecological condition. Increasing water storage capacity in the basin by e.g. small dams (Add store, Scenario 11, 12, 15) does not have ecological benefits apart from the Pangani River below the Nyumbaya Mungu Reservoir (PBWO/IUCN 2009).

There are tradeoffs involved in every scenario. The overall picture is that there is no one scenario that is beneficial in terms of all three criteria - economic, social and ecological (Figure 1). Economic outputs were generally the most sensitive, with differences between scenarios frequently being greater than 20%. Social wellbeing within the basin changes negatively under most scenarios, but by a relatively small percentage. Strategies that can be recommended to decision makers include improving the efficiency of irrigation systems, optimizing flow patterns for improving river health, and exploring options around managing hydropower production which can improve environmental flows downstream.

Table 2: Gains or losses for different sectors and scenarios per year in the Pangani basin in million US$ (converted from Tanzanian shilling (Tsh) using a conversion rate from 2009 of US$ 1 = 1344.28 Tsh) Source: adapted from PBWO/IUCN (2009)

	Present Day (PD) flows	1. Maximise Agriculture	2. Maximise Hydropower (HEP)	4. Optimising PD + HEP	5. Maximise River Health (High Environ)	15. Add storage and optimise PD
Hydroelectric Power*	**1770.94***	**- 451.43***	**407.65***	**411.08***	**- 3.00***	**18.83***
Agriculture	**150.56**	**11.56**	**- 28.92**	**- 51.60**	**- 46.71**	**- 38.21**
Natural Resources	**25.89**	**0.13**	**- 0.38**	**- 0.12**	**0.49**	**0.45**
Ecosystem services	**0.24**	**- 0.07**	**0.14**	**0.25**	**0.24**	**0.14**
Total	**1947.64**	**- 439.80**	**378.48**	**359.61**	**- 48.99**	**- 18.79**
% change		**- 22.58**	**19.43**	**18.46**	**- 2.52**	**- 0.96**

**Hydropower production in the Pangani River Basin contributes about 17% to total electricity production in Tanzania (Turpie et al. 2005). The economic value of hydropower production was determined in terms of differential in unit power production costs between hydropower and the next best alternative energy source.*

What policy uptake resulted from examining the ecosystem services?

Following this technical analysis the focus switches to stakeholders and government. Once a strategy is agreed on the next sequence the technical work will begin. This would be to help lay out a basin water-management plan, which would guide future decisions on water allocations, and a monitoring programme, which would check if the environmental flows are being maintained in the river, and the agreed desired river state is being achieved.

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