Preliminary Economic Assessment of Water Resources of the Pangani River Basin, Tanzania

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Abstract

A study was conducted in Pangani River Basin to provide estimates of the value of water in different uses and review various issues and economic tools pertaining to water resource allocation and financing mechanisms in the basin. The study was carried out in October-November 2003, and was based on existing literature, GIS data, interviews, focus group discussions and a household survey. Preliminary findings on the value of water in alternative uses indicated that for irrigated agriculture such as coffee, the estimated average value was about Tsh. 700 – 6000/m^3. Water was estimated to be worth Tsh. 30 – 100/m^3 in large scale sugar production, Tsh. 3500 – 5300/m^3 for greenhouse-based cut-flower production, Tsh.200 – 600/m^3 for small scale traditional furrow irrigation agriculture, and Tsh. 600 – 1400/m^3 for improved irrigation agriculture schemes. Water prices for domestic consumption were equivalent to Tsh. 1500 and 1250 per m^3 in the highlands and lowlands respectively.

Key words: Economic valuation, Water, Pangani Basin, Instruments, Incentives

Introduction

As water resources become increasingly scarce in Africa, the need for the use of economics to aid in decision-making and management becomes apparent. Indeed, global experience shows that economic approaches are increasingly becoming useful in water management issues. Water is the basis of the economy as well as essential for human life and biodiversity. The Pangani River Basin in north-eastern Tanzania provides a good starting point for evaluating the economic issues around water resources and how economics can be used to improve their management to align with national goals.

Tanzania has committed itself to an ambitious poverty reduction strategy, and plans to transform itself into a middle-income country by 2025. This will require massive economic development and growth. Yet Tanzania faces water scarcity in some cases, at least partly due to the inefficiency with which water is used. This scarcity has been exacerbated by population and economic growth which has not been accompanied by improved resource management. Fortunately, Tanzania has adopted a progressive National Water Policy that aims at sustainable development and management of water resources. A Water Resources Strategy and Legislation are being drafted. For the first time, water allocation will consider both human needs

and environmental protection. In addition, the policy aims to implement fees for financing water resources management and to use economic and other instruments to manage the use of water resources and ensure long term sustainability.

The principal concerns affecting water resource management in the Pangani basin are:

- Threats to water supply – due to climate change, forest degradation, inefficient uses and pollution;
- Increasing demand for water – due to population and economic growth;
- Shortages for power generation – due to upstream water abstraction and siltation of dams;
- Conflicts over water resources – between different sectors and between upstream and downstream users;
- Environmental degradation – due to reduction in water flows necessary to sustain ecological processes and sustainable livelihood practices;
- Insufficient funds for water resources management – inadequate government funding exacerbated by lack of income from users;
- Cultural heterogeneity – the diversity of users and their relationships with the environment creates challenges for water management.

The Pangani River basin and its management

The Pangani River drains a basin of 43 000 km^2 in north-eastern Tanzania and a small part of Kenya. The basin contains fourteen districts and two municipalities, falling within the Kilimanjaro, Manyara, Arusha and Tanga Regions of Tanzania. Mount Kilimanjaro and Mount Meru provide the main source of river flow, and the basin also drains the Pare and Usambara Mountains in the north-east. Numerous tributaries drain the mesic highland and upper basin areas, whereas water is far scarcer in the arid lowland areas, with the Pangani River being a prominent feature in the landscape. In addition to several small natural lakes, a dominant feature is the 14,000 ha Nyumba ya Mungu Dam located on the Pangani River in the upper basin (Rohr and Killingtveit, 2002). Several wetlands exist in the basin, most notably the Kirua swamps downstream of Nyumba ya Mungu, which cover 90,000 ha. The highland and upper basin areas are characterised by urbanisation, densely populated rural areas and cultivation. The lowlands have scattered croplands associated with smaller settlements, usually close to the Pangani River. Arid rangelands make up much of the remaining landscape. The total population of Pangani River Basin is approximately 2.6 million. Population growth rates are up to 4.0% in the highland areas (Arusha Region) but relatively low towards the coast (1.8% in Tanga Region).

While water supply depends primarily on precipitation in the highland areas, it is greatly affected by management of the whole catchment, particularly in the highlands. Natural forest cover encourages infiltration of water during the rainy season, which is then released gradually, maintaining flows throughout the year. As forest and other vegetation and soil cover are degraded, so less water infiltrates and more water is lost during flood periods. The quality of water supply is also affected by catchment activities, which lead to soil erosion and pollution.

Water resources of the Pangani River Basin plus three much smaller basins (total 56 000 km^2) are managed by the Pangani Basin Water Office (PBWO), which allocates user rights for water. Most water is allocated to the higher lying areas. The natural environment has not been considered as a consumer of water and has therefore not received direct water allocations. Environmental resources have been affected as far as the Pangani estuary, where saltwater intrusion is a problem, and the associated near-shore environment, where some farming and fisheries are thought to have declined as a result of decreased freshwater flows.

The objectives of this study were to provide estimates of the value of water in different uses within the Pangani River Basin, as well as to review various issues and economic tools pertaining to water resource allocation and financing mechanisms for Integrated River Basin Management (IRBM). This study was conducted with a view to providing the preliminary understanding required to design more detailed research that will inform the sustainable, efficient and equitable allocation of water in the basin. Activities investigated included irrigated agriculture, ranging from large scale commercial coffee estates to small scale traditional furrow irrigation, water for livestock, domestic use, use of aquatic ecosystem goods and use in hydropower generation.

Study methodology

The study was carried out in October-November 2003. Information on the study area was collected through literature, interviews and visit to the study area. Biophysical information was obtained from existing GIS data and population estimates were obtained from the recent (2002) census. Water use was described on the basis of data from the Pangani Basin Water Office. The value of water in large-scale commercial agriculture was estimated on the basis of interviews with farm managers, while the value of water in small-scale agriculture and the value of aquatic natural resource use was estimated from data collected in key informant interviews, focus group discussions and a household survey of 203 households in 14 villages located in four parts of the Pangani River Basin: the highland areas, upper basin, lower basin and around the Pangani estuary. Domestic water use was estimated and valued from survey and municipal data. The value of water power production was estimated based on information supplied by TANESCO. Values are in Tsh, where Tsh1000 = US$1. The study was carried out in a very limited time frame and with very small sample sizes. The results are not intended for direct use in water allocation decision-making, and it is important to view the results as a preliminary description that will help to guide future research.

The Value of Water Consumption

Domestic Consumption

Domestic consumption of water could be considered to be the most important type of water use in the basin, in that it is vital to human wellbeing. Tap water is supplied to major urban areas, smaller towns and a large number of rural villages. However, a

large proportion of the population relies on fetching their own water from rivers and wells (rural population of Pangani River Basin = 2.16 million, urban population = 427,000). Urban consumption is estimated to be in the region of 70 litres per person per day, while rural consumption is about 37, 22, 18 and 28 litres per person per day in the highlands, upper basin, lowlands and coastal areas respectively. The value of water for domestic use is probably better reflected by the willingness to pay, demonstrated through trade of water in rural areas, than by prices set by authorities in the urban areas. Water prices are equivalent to Tsh 1,500, Tsh 1,250 and Tsh 1,200 per m^3 in the highlands, lowlands and at the coast respectively, far higher than the prices charged by PBWO. The total value of domestic water supplies in Pangani River Basin is estimated to be in the order of Tsh 37 – 46 billion.

Irrigated Agriculture

Agriculture is the biggest user of water with over 50,000 ha of fields irrigated in Pangani Basin. This includes large commercial estates (mainly coffee, also sugar), flower farming and small-scale mixed cropping. Small-scale farmers have plots of about 0.1 – 0.2 ha in the highlands, increasing to 0.8-1.5 ha in the lowlands.

Coffee is Tanzania's largest export crop. It is produced on large estates and by small-holder farmers. Production is strongly correlated with rainfall and irrigation inputs. Large scale coffee production in the study area consumes an estimated 1,000 m^3 per ha per year (excluding processing), generating an average income of about Tsh 700 – 6,000 per m^3 of water consumed. Sugar production is mostly on large-scale, but small-scale farmers also grow it. About 85% is sold locally, the remainder being exported. Sugar consumes about 12 – 17,000 m^3 per ha per year (excluding processing), with an average value added of roughly Tsh 30 – 100/m^3 water. The greenhouse-based cut-flower industry covers a total of 80 ha, and is mostly for export. Water consumption is estimated to be about 18,250 m^3 per ha per year, but average value added is estimated to be as high as Tsh 3,500 – 5,300/m3 (See Table.

Small-scale farmers make use of an estimated 2,000 traditional furrows which tap water supplies from springs and rivers. Some of these have been improved in more modernised irrigation schemes, with a result that efficiency of water use ranges now from less than 15 to over 50%. Over 20 different crops are grown by small-holders in the basin, with most farmers growing a variety of fruits and vegetables. Maize is the most ubiquitous crop, both in irrigated and non-irrigated areas. Coffee is grown by most households on Mount Kilimanjaro and Mount Meru. This is usually grown in association with maize and bananas by almost 90% of households in this area. Bananas are also grown by about one third of households in the lowlands. Tomatoes are grown in all areas, but tend to be more frequent in irrigated areas, particularly in the highland areas. Beans are very commonly grown in the upper basin and in highlands, but not in the lowlands.

While the highlands are too cool for rice production, rice is a major crop of irrigated areas in the upper basin, and to a lesser extent in the lowlands under irrigation or in close proximity to flooded areas. Farmers in the highlands and upper basin that do

Table 1. Average value per m^3 of water in different uses. These are rough estimates only*.

Type of use	Estimated water consumption	Estimated average value (Tsh per m^3)
Domestic use	18 – 70 m^3/head	1200 – 1500
Coffee estates	1000 m^3/ha	723 – 6205
Sugar estates	12 – 17 000 m^3/ha	32 - 101
Flower farms	18 250 m^3/ha	3500 - 5300
Small scale irrigation		
Highland traditional furrow	3000 m^3/ha	211
Upper basin traditional furrow	3000 m^3/ha	475 – 574
Upper basin improved schemes	850 – 1195 m^3/ha	574 – 1400
Lowland traditional furrow	3000 m^3/ha	109
Livestock		
Highlands (dairy cattle)	36 m^3/head	2263
Upper basin (dairy & beef cattle)	27 m^3/head	860
Lowlands (beef cattle, goats)	18 m^3/head, 2.5 m^3/head	479 – 926
Aquatic ecosystems	?? m^3/ha wetland	Still unknown
Hydro-electric power production	2.4 -19 m^3/kWh	73 – 300(?)

*Estimates are based on a study conducted in Oct-Nov 2003, which entailed interviews with TANESCO, municipalities, estate managers, irrigation scheme representatives, and 203 households in 14 villages in four parts of the basin. For full details see Turpie *et al.* (2003).

A note on water values:

It is important to note that the average values presented here are not values upon which water allocation decisions should be based. The average value of water in different productive activities is a problematic concept, because it is impossible to 'allocate' the net benefit of a production activity to any one of its inputs, such as water. The measure that is actually required is the net marginal value of water in different uses. This is the added value gained by adding an extra unit of water to any particular use. As more water is allocated to any particular use, the added value will diminish. This sort of value is determined by the construction of data-intensive production functions in which the change of output can be predicted for a change in water input, and should be the focus of future studies.

not have access to irrigation concentrate their efforts on maize, beans and onions, as well as a variety of fruits and vegetables. Sugarcane is a minor crop on smallholder farms, but is grown throughout the basin. Cassava is only grown in the lowlands, as are peri-peri, paprika and fiwi. Okra is more commonly grown in the lowlands. Around the Pangani estuary, farmers concentrate on coconuts, betelnuts, cassava, sweet potato and pumpkin, as well as maize and bananas, but there is very little irrigation.

Survey data from a small sample of households throughout the basin suggests that gross income from crops is typically in the range of Tsh 350,000 – 600,000 per household per year. However, much higher incomes have been reported from traditional furrow systems in the upper basin, in some cases higher than that of improved irrigation schemes. Nevertheless, it is easily demonstrated that irrigated areas produce higher incomes per ha than fields without irrigation in the upper basin. This is not necessarily the case in the Kirua swamp area where similar incomes are obtained from crops grown within regularly-flooded areas to those from furrow irrigation areas nearby. The non-irrigated agriculture around Pangani estuary yielded similar incomes per ha to the rest of the lowland areas. Estimated average gross income per m^3 of water used ranges from Tsh 100 – 1,400, depending on the area of the basin and the type of irrigation (For full details see Turpie *et al.,* 2003).

Livestock

Livestock are kept throughout the basin. In the highland and upper basin areas, households keep small numbers of cattle and goats and sometimes sheep. In the

densely-populated highland and upper basin areas, most cattle are stall-fed ('zero-grazing') dairy cattle, but a few households in the upper basin have larger herds (up to 32), which are grazed. In the lowlands, cattle and goat herds are much bigger, and are almost all associated with the Maasai community, who are also the only community keeping donkeys. Other tribes in this area keep very few livestock, mainly small numbers of goats. Very few households close to the keep livestock. Income per unit of water consumed ranged from Tsh 480 - 2,300, being highest in the highlands, but was also high for Maasai herds in the lowlands.

Environmental Goods and Services

Water supply in the Pangani River Basin is crucial to the functioning of the basin's aquatic ecosystems. Apart from the intrinsic value of these ecosystems, they provide goods and services that contribute to the economic wellbeing of inhabitants of the basin. These include aquatic plants such as reeds, sedges, mangroves, food and medicinal plants and aquatic animals, including fish, crocodiles, hippos and water birds that can be harvested for household consumption or sale. The supply of all of these goods and services is affected by the quantity and quality of runoff in the catchment. Their value is determined by the degree of use and the sustainability of that use.

On average, households derive modest incomes from aquatic resources, increasing from a very small amount of income in the highlands to fairly large amounts in Pangani estuary. Fisheries are the major source of income from aquatic resources, but palms also make a substantial contribution. The value of plants such as reeds and sedges is small, but this belies the degree to which they are used. Their low value is due to their relative abundance The value of mangroves is probably underestimated. Although income from aquatic resources is small, they are significant in the context of overall household income. The perception by households themselves is that aquatic resources contribute some 4-23% of household income (including subsistence value).

Linking the value of aquatic ecosystem goods and services to flow is more problematic, however. Calculation of the average value per m^3 water would require relating the supply of these goods and services to the overall annual flows in different parts of the basin. This would not be a particularly useful measure, however, since the relationship between flow and the production of ecosystem goods and services is complex, and is yet to be studied in the Pangani River Basin.

More importantly, as is true for all of the value reported in this study, the average values calculated are not as important as understanding the marginal value of water in different uses. For example, how will reed supply change if water allocation to the environment changes in a particular area? Such estimates can only be made in conjunction with a scientific study.

Table 2. Overall average value per household derived from harvesting of aquatic resources (including value added in processing), averaged across user and non-user households (Tsh per year)

	Highlands	Upper basin	Kirua Swamp	Pangani estuary
Food & medicinal plants	63	815	2 383	170
Reeds, sedges and grasses	2 120	2 433	2 852	0
Palms	0	4 269	4 434	86 721
Mangroves				7 890
Reptiles, mammals & birds		6	8	
Fisheries		392	33 883	693 012
Average total income per household	2 183	7 915	43 560	787 793

Hydropower Production

Pangani River makes a substantial contribution to Tanzania's electricity supply. The country's power supply is mainly from hydropower, with three Hydro-electric power stations in the basin, at Nyumba ya Mungu, Hale and New Pangani Falls, contributing 17% of the country's capacity. The power output never reaches the installed capacity, however, due to shortages of water flow. Power production at Nyumba ya Mungu relies on storage of water in the dam during rainy seasons and then a relatively constant release of water through the turbines. This regulation by the Nyumba ya Mungu dam also ensures a relatively even flow to the downstream power stations at Hale and New Pangani Falls. The latter are more modern and translate flow into power far more efficiently, with New Pangani Falls being 8 times more efficient than Nyumba ya Mungu in terms of output per unit of water. The average price obtained per unit of power is Tsh 73/kWh. However, the value of power generation in terms of its impact on national economic output would be far higher.

Conclusion

Integrated River Basin Management in the Pangani Basin will ultimately need to strive towards the optimal allocation of water among different types of uses in different parts of the basin, with the environment being seen as a legitimate user. This will be best achieved through more rigorous study of the economic benefits of water in alternative uses in different parts of the catchment, together with the use of a multi-criteria decision tool that can take other goals into consideration.
The values presented are preliminary estimates of the current value of water in different uses and gives an idea of the orders of magnitude involved for some uses of water in certain parts of the Pangani River Basin.

It is important to note that the average values presented in this paper are not values upon which water allocation decisions should be based. The measure that is actually required is the net marginal value of water in different uses. This requires an understanding of the relationship between flows and resource productivity, in conjunction with an understanding of demand of these resources. This in turn requires multidisciplinary research and is often dependent on the existence of long term data series on both flow characteristics and biological aspects.

There is a need to explore some of these relationships by collecting information on the economic, environmental and social costs and benefits of various water allocation scenarios.

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