The Socioeconomic Causes and Impacts of Modification of Tana River Flow Regime

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Abstract

The flow regime of River Tana has been altered by a number of socioeconomic activities upstream. Modification of the flow regime of the river has had significant effects on the natural resources allied to the river, its economy and the general welfare of people. The study aimed at establishing the social and economic causes and impacts of modification of the Tana River flow regime. Results indicated that the main causes of modification of River Tana flow regime include hydropower generation, irrigated agriculture, abstraction of water for domestic and industrial use, and pastoralism. The demand for hydropower and food has also increased following the 35% increase in population between 1999 and 2009. The socio-economic impacts of modification of River Tana flow regime have been manifested in freshwater shortage downstream particularly during drought periods. Low levels of water flow in the river during the long drought periods put considerable constraints on irrigation activities. The freshwater shortages have further resulted in confrontations between pastoralists and crop farmers over grazing areas and watering points leading to loss of lives. Waterborne health disorders arise from unsafe water sources and affect human communities. It is recommended that investments should be channeled towards water treatment programs for the population in this area. There is need to come up with appropriate integrated resource management for sustainable utilization and management of water and land resources in the basin. The arid areas still remain the most significant source of beef and other livestock products hence there is need to provide water services to reduce conflicts with other demanding sectors especially competition for watering points.

Keywords

Socioeconomic activities • Modification of river flow • Hydropower generation • Irrigated agriculture • Freshwater shortage • Demand

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Introduction

River Tana is the longest river in Kenya with a total length of approximately 1000 km and catchment area of 100 000 km^2 (IUCN 2003). The river has its source in the eastern slopes of the Aberdares and southern slopes of Mount Kenya (Maingi and Marsh 2002). It flows through semi-arid and arid regions of Kenya as it flows to the Indian Ocean. In its lower course, the river meanders through alluvial floodplains and forms a delta as it enters the sea. The long-term and short-term flooding of River Tana strongly influences the ecology of the flood plain as well as the formation and distribution of wetlands. Traditionally, River Tana floods twice a year; in May–June and November–December. These floods resulted in deposition of a fertile layer of silt on the floodplain. The lower sections of River Tana support unique wetland ecosystems such as riverine forests, oxbow lakes, floodplain grasslands, mangrove forest, sand dunes and coastal waters. The riverine forest along the River Tana is an isolated remnant of a continuous rainforest belt that extended between the Congo Basin and Kenya Coast during the moister periods of the Pleistocene (Terer et. al. 2004; Susanne 2004; Allison and Badjeck 2004).

River Tana and its associated wetlands provide livelihoods, income, and socio-cultural benefits to the local people. It also harbours threatened species of primates, fish (De Vos et al. 2002), birds (Bennun and Njoroge 1999) and plants. The local people have traditionally exploited and developed strong connections with the wetland resources within the river basin. Traditional land-use practices of small-scale agriculture, pastoralism and fishing have maintained the ecological balance of the Lower Tana for thousands of years. However, the rapid population growth has resulted into forest fragmentation and use of improper farming practices such as bush burning and shifting cultivation (Wieczkowski 2002).

Like the rest of the world where the natural flow of majority of rivers has been substantially altered through dam construction as observed by Maingi and Marsh (2002), the flow regime of River Tana has been altered by damming and other human activities. Five multi-purpose dams have been constructed on the upper reaches of the river namely: Kindaruma dam (1968), Kamburu dam (1975), Gitaru dam (1978), Masinga dam (1981) and Kiambere dam (1988). A new multi-purpose dam has also been proposed for construction at Mutonga-Grand Falls just below the first five dams. Dam construction has affected the river's downstream flow and physical characteristics, as it regulates water-flow and decreases the frequency and magnitude of flooding (IUCN 2003). Modification of the river's flow regime has had significant effects on the natural resources allied to the river, its economy and the general welfare of people. The study aimed at establishing the social and economic causes and impacts of modification of the Tana River flow regime.

Socioeconomic Impacts

In this section we discuss both negative and positive socio-economic impacts of modification of the flow regime of River Tana. The socioeconomic impacts include negative impacts on livelihoods and food security, increased conflicts, displacement of people from their traditional homes, scarcity of potable water (freshwater), and disruption of social organization, among others.

Negative Impacts

Before the construction of the five multipurpose dams, River Tana used to flood its banks twice a year. However, since 1989 when the last dam was commissioned, flooding has decreased dramatically in both volume and frequency (IUCN 2003) with resultant socioeconomic consequences. The poor indigenous people and other ethnic minorities downstream bear the disproportionate share of these social and economic impacts without gaining any commensurate share of the economic benefits. This confirms the observation by Beck et al. (2012) that river damming mostly affect marginalized people whose livelihoods entirely depend on riverine resources. The socio-economic impacts of modification of River Tana flow regime have been manifested in freshwater shortage downstream particularly during drought periods. Low levels of water flow in the river during the long drought periods put considerable constraints on traditional economic activities.

Conflicts Due to Limited Dry Season Pasture and Watering Points

Over 240,000 people who reside in Tana River County (Republic of Kenya 2010) are engaged in agriculture, livestock keeping and fishing in areas that are adjacent to the River and the Tana Delta. Most of these people depend on the river's flooding regime for their livelihood activities. Approximately 2.5 million livestock, including over a million cattle, depend on River Tana's floodplain grasslands and water bodies for dry season pasture and water (CADP 1991). During prolonged droughts there is influx of cattle from neighboring counties as pastoralists migrate to the Tana delta in search of pasture and water. The decrease in the flooding regime caused by construction of the existing dams has limited dry season pasture and watering points to the area that is directly adjacent to the river. This has disrupted the traditional patterns of transhumance (the seasonal movement of people with their livestock between rainy season and

dry season pastures), increased grazing pressure, and resulted in intensified confrontations between pastoralists and floodplain agriculturalists (Goldson 1994) over grazing areas and watering points. The conflicts sometimes lead to loss of life particularly at the Tana delta. In August 2012, 52 people were killed in ethnic violence in Tana River County between agriculturalists and pastoralists (http://en.wikipedia.org/wiki/Tana_River_County).

Reduction in Floodplain Agriculture

Over 115,000 people depend on flood recession and riverbank farming along the river and at the delta (Emerton 2003). These farmers depend on floodwater to irrigate their crops and on the depositions of fertile alluvial soil. As is the case in many countries in Africa where dam construction has led to the disruption of many traditional production systems including flood recession agriculture (Maingi and Marsh 2002), the agricultural activities in the Tana River basin are interrupted by retention of floodwater in hydroelectric power dams that are located upstream (Hirji et al. 1996). The dam construction has regulated the volume of water that flow downstream, controlled floods and reduced floodplain agriculture. It is likely that after the construction of the sixth dam which is planned at Mutonga-Grand Falls, the farmers will limit their farming to riverbanks only. The reduction in farming area may adversely impact on agricultural production and food security, resulting loss of income and poverty among the local communities.

Reduced Fish Landings from Ox-Bow Lakes

As already highlighted, the natural flooding regime of River Tana has been disrupted by dam construction and other anthropogenic activities which occur upstream. Communities downstream at the river delta have reported noticeable decline in river size as well as decline in the sizes of oxbow lakes (Terer et al. 2004). The ox-bow lakes are important for fish production. A big population also depends on fishing as a source of income and household protein. River Tana, its delta and estuary area support both subsistence and commercial fisheries, providing the main livelihood for more than 50,000 people (Nippon Koei 1998; CADP 1991). Modification of the river flow regime has therefore negatively impacted on the fish production from the ox-bow lakes. It is thought that additional dam construction will rapidly exacerbate this decline in fishing area and catch (Mavuti 1994).

Displacement of People and Shortage of Fresh Water for Domestic Use

The construction of the five dams in the upper reaches of River Tana displaced communities from their traditional homes and impacted negatively on their human wellbeing. Displacement of communities led to the weakening of social networks and other traditional systems that supported human wellbeing. Socially, the displacement separated families and clans that traditional lived together in one place enjoying a common sense of belonging and social networks. Psychologically, this separation of families and clans caused some trauma to the affected people.

The displacement also led to loss of access to the river water which served as a common property resource for the local communities. As highlighted earlier, the local communities traditionally depended on the river water for their livelihoods. It was expected that besides compensation for their land, the project would provide basic things such as supply of potable water to support the displaced populations in the areas where they built their new homes. This study has however revealed that the benefits from damming have not trickled down to those communities whose living conditions were affected by the project. The displaced communities obtained land far away from the river which is their main source of potable water. Consequently, during droughts the women and children have to walk longer distances to collect fresh water for domestic use. This has further impacted negatively on those economic activities that rely on labour provided by women. The population within the Tana basin that can access safe drinking water within reasonable distances has continued to decline. About 78% of the households in Tana River County depend on fresh water supplies from the river, pond or dam and spring or well while only 11% have access to piped water. Waterborne health disorders arise from unsafe water sources and affect human communities.

Disruption of Traditional Norms and Values

Social interactions between the local communities and migrants from other areas who worked in the dams and power stations during the construction phase as well as those who are currently working in the power stations have both positive and negative impacts on the traditional norms and values of local communities. The dam construction resulted in the establishment of temporary towns or areas of high population concentrations with intricate relationships that diluted the traditional norms and values. These temporary towns eventually fizzled out after completion of the dams.

Public Safety

Public safety concern is a problem and it may include accidents from sudden peak releases downstream in the dry season. Dam construction led to relocation of households as well as a permanent loss of arable land and hence reduction of agricultural production.

Positive Impacts

Provision of Employment to the Local People

Despite the negative impacts, modification of stream flow has also provided benefits (Doyle et al. 2000). Some members of the local population particularly from the upper reaches of the river obtained employment as construction workers during dam construction. This employment was however only available for a limited period during dam construction since after the completion of dam construction, the labour was no-longer required. Some members of the local population also got employed by the Kenya Electricity Generating Company (KenGen) while others were employed as security guards. In addition, dam construction created market for local produce and provided opportunities for the growth of small-scale businesses that further provided self employment or supplementary source of income and livelihood to the local population. Although the market eventually reduced after the construction phase, the employees of KenGen who remained behind to work in the power stations have continued to provide a market for some local produce. Expanded market for local produce has similarly been reported elsewhere by Canter (1985).

Improved Transport Infrastructure

Transport infrastructure has been improved in the upper course of River Tana to support hydropower generation activities at the five dams. This road network has improved transport for the local people who are now able to commute without difficulties.

Fish Production from the Tana River Dams

The fish production in River Tana averages about 1000 MT annually and is an important source of protein, income and employment to the local communities. While fish production from the ox-bow lakes at the river delta is negatively affected by modification of stream flow, the dams have become important sources of fish upstream. The main types of fish are Tilapia spp. (50%), Common carp (29.5%) and Clarias (20.3%). The other fish include Eels, Barbus, Labeo and Moromyrids which contribute less than 0.5% of the total fish landings. Despite fisheries being an old occupation within the Tana River basin, commercial fisheries in dams began in 1981 at Masinga dam, while that of Kamburu and Kiambere dams began in 1988 and 1991 respectively (Emerton 2005). There is however no fishing activity at Gitaru and Kindaruma dams because the two are heavily infested by crocodiles.

Generation of Electricity

Hydropower is a clean and cheap source of energy. It is associated with minimal production of dangerous gases, limited solid waste, and one of the cheapest sources of electricity compared to other sources such as thermal plants. Experience gained from using electricity generated from thermal plants during years when prolonged droughts occurred showed that the price of thermal electricity always doubled that of hydropower.

Causes of Modification

The socioeconomic impacts of modification of the flow regime of River Tana have been caused by a number of immediate and underlying root causes (Fig. 1). The analysis of both immediate and root causes is critically important because the socioeconomic impacts could only be effectively tackled by addressing the respective root causes.

Immediate Causes of Modification

The main immediate causes of modification of River Tana flow regime include hydropower generation to meet the growing demand for energy and water abstraction for irrigation and domestic supplies. Hydropower generation currently produces 481 megawatts (MW) but has a potential of 960 MW. Irrigated agriculture currently covers 54,676 ha with a potential of 132,000 ha. Water is also abstracted for domestic and industrial use as well as for livestock.

Hydropower Generation

Since the mid 1960's River Tana has been heavily dammed upstream for multi-purpose activities, though hydropower generation has always been the main driving force for the construction of these dams. Five major dams have been constructed on the river with the aim of harnessing water for hydroelectric power generation. These dams are Kamburu, Kiambere, Gitaru, Masinga, and Kindaruma (VandenBossche and Bernacsek 1990; Boboti 1996). Total hydropower potential for the river is estimated at 960 MW compared to the present output of 481 MW (GOK/JICA, 1992). A new hydropower scheme has been proposed for construction at Mutonga-Grand Falls on the Tana River below the five existing dams. In recent years, hydroelectric power generation has been affected due to low levels of water in the dams caused by droughts. Apart from hydropower generation, the two large reservoirs at Masinga and Kiambere were developed with capacities meant for river flow regulation.

In addition, there are minor dams in the upper catchment for public water supplies, namely Sasummwa, Thika, and Ruiru. Other smaller dams have also been constructed for purposes of irrigating coffee, horticulture, and floriculture. Despite the economic benefits associated with damming, local and downstream communities suffer from its negative

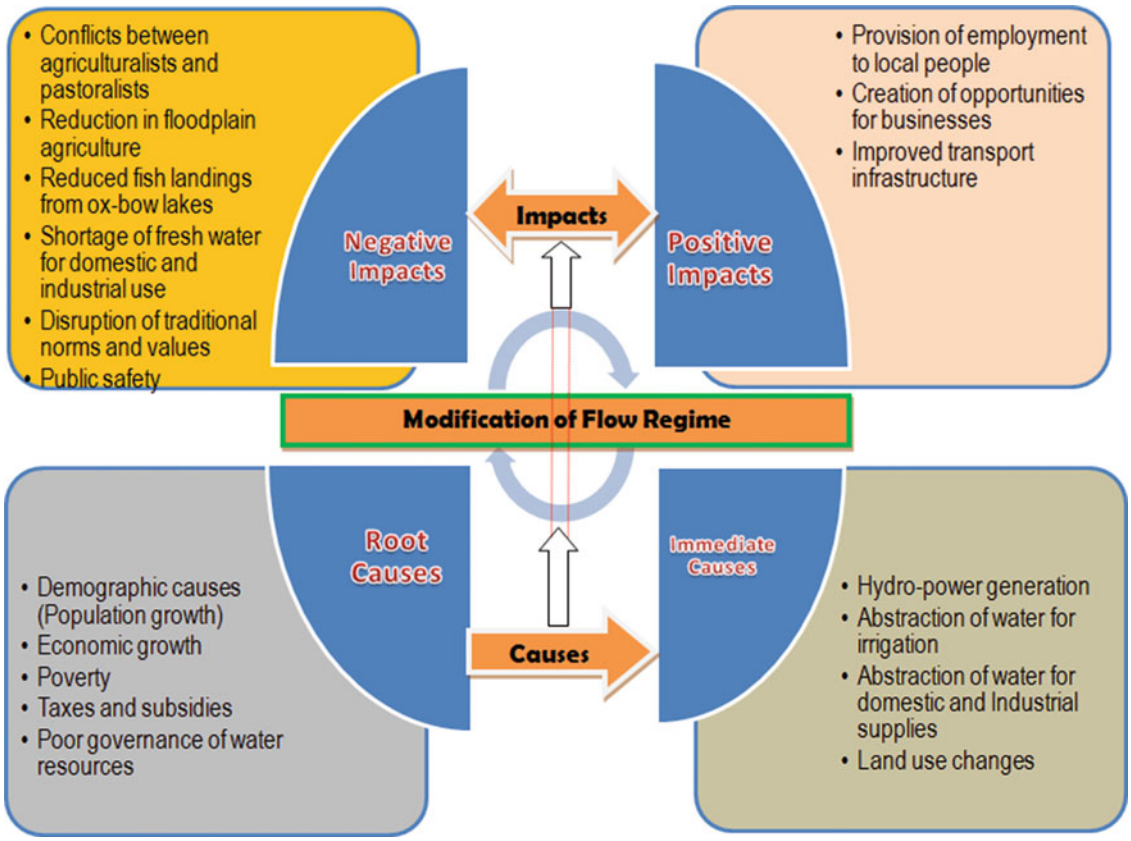

Fig. 1 Diagrammatic summary of the analysis of the causes of modification of River Tana flow regime

consequences. Damming had a major influence on the river's downstream flow and physical characteristics, most notably through regulating waterflow and decreasing the frequency and magnitudeof flooding (IUCN 2003).Families who were displaced by the hydroelectricity generation project were given minimum compensation yet this project altered their livelihoods (GOK-JICA 1992).

Irrigation Agriculture

Water is abstracted from River Tana to satisfy irrigation needs. The River Tana basin has a potential of 132,000 ha for irrigation development (Agwata 2005). Public irrigation schemes located within the basin are partially or entirely managed by quasi government organizations particularly the National Irrigation Board (NIB), the Tana-Athi Rivers Development Authority (TARDA), the Agricultural Development Corporation (ADC) and the Bura Management. The area presently under irrigated agriculture is about 54,676 ha. (GOK/JICA 1992; Agwata 2005) encompassing 30,148 ha of private development and 24,528 of Government irrigation development schemes.

The irrigation project by TARDA as well as Bura irrigation and settlement programme and the Hola irrigation scheme have been dormant for some time (Republic of Kenya 1997, 1999). With the planned revival of these major irrigation schemes as stated in the strategies of the Ministry of Regional Development (GOK 2003), abstraction of water for irrigation is likely to increase tremendously with Tana Delta Irrigation scheme being a major abstractor of water from the Tana River (GOK-TARDA 1982a, b, c). This would further have significant negative impacts on the downstream communities as well as on the marine environment since the type of irrigation being practiced does not promote efficient use of fresh water. While abstraction for domestic use has not been regulated in the rural areas, failure to regulate large-scale abstraction for irrigation is a serious problem considering the quantity of water involved.

In the upper course of the river there are private irrigation schemes using sprinkler irrigation. Small-scale schemes are based along Thanantu, Rubungazi, Thuchi, Thiba, Sagana, Thika, Yatta Canal, and Chania sub basins. The schemes are gravity-fed except lower Tana River where pumps or furrow and basin type irrigation methods are used. The minor irrigation schemes have been established by groups of farmers and are covering a total of 1,483 ha. The projects being implemented in the catchment area are highly intensive requiring substantial amounts of agro-chemicals to enhance the yields (CBS 1998).

Abstraction of Water for Domestic and Industrial Use

Abstraction of water for various purposes is a significant immediate cause of fresh water shortage and modification of river flow in the Tana basin. Management weaknesses with regard to large-scale water abstraction are evident. The Ministry of Water Resources Management and Development in Kenya is responsible for regulating water abstraction (GOK-JICA 1992; GOK 2003). Water is also abstracted to meet the high demand for freshwater for domestic and industrial uses in Nairobi City. To achieve this, the following dams have been constructed in the upper reaches of the river.

- Thika dam located at Ndakaini in Thika sub-county was completed in 1994 with a capacity of 77 million m^3 and linked to Chania River by 4 km tunnel
- Sasumwa dam located at Njambini, Nyandarua was constructed in two phases. The first stage was completed in 1955 and the second completed in 1968. The dam has storage capacity of 15.9 million m^3 and is on Sasumua River but receives Kiburu and Chania waters. The dam has a pipeline to Kabete 60 km. Currently the dam yields 52,80m^3/day but has a design yield of 59,000m^3/day.

Land Use Changes

Over the years, land use patterns have been shifting from the more traditional and sustainable agricultural practices and forest harvesting to less environmentally friendly practices. This shift is being attributed to increased population that exerts pressure on the scarce arable land. The rapid population increase in the Tana basin has led to increased demand for agricultural land with consequent unsustainable expansion of agricultural activities and human settlements in the catchment areas. Nationally, there is increasing concern over the rate at which forests and other vegetation that hold soil on the slopes are being cleared to pave way for agriculture and human settlement on the one hand, and to provide timber and fuelwood that are in high demand. The Tana River basin extends over areas of different agricultural potential with some areas being categorized as high, medium and low potential. According to GOK (1979 and 2003), the changes in land use practices are exemplified by decrease in the size of forestland due to conversion of forests to farmland for the cultivation of tea, coffee, and maize and for human settlement. It has been observed that in the 1920s, coffee and tea were grown on 10,000 and 5,000 ha respectively while at present; coffee and tea cover 500,000 and 150,000 ha respectively (Odingo 1971; GOK 1979, 1984, 1994; McMaster 1969; Othieno 1989). In addition, there is increased cultivation on steep slopes and riverbanks without applying basic soil conservation measures, and encroaching into the forest lands and other marginal areas. In the recent past, there has been extensive destruction of forests on the main water catchment areas of the Aberdare (Nyandarua) ranges and Ngong Hills. These changes in land use have led to serious soil erosion resulting in increased sediment loads in rivers. Similarly, there is the problem of overgrazing by the pastoralists who keep large herds of cattle in a fragile semi-arid environment, particularly in lower parts of the river basin.

Root Causes of Modification

Six root causes have been identified and classified under three broad categories as demographic, economic, and governance causes.

Demographic Causes

Demographic factors particularly high population growth and urbanization exerts pressure in the freshwater from the River Tana. This high population growth is due to both natural population growth and in-migration in the river basin. Major urban areas in Kenya fall within this river basin. A number of other significant towns such as Thika and Hola also exist. The growth in economic activities in these urban areas requires increased energy supply. High population has led to high demand for energy because economic activities depend heavily on energy supplies most of which is derived from hydropower. The Government of Kenya has since the mid 1960's constructed reservoirs on River Tana for this type of energy. These reservoirs impact negatively on downstream population especially during the dry seasons, as water has to be retained in the dams for generation of hydropower. In addition, rapid population leads to high dependency ratio thereby worsening the incidence of poverty. A large and increasing youthful population needs basic education and intensive health care thereby limiting the scope for investing in other productive activities. As a result, employment opportunities are not created and it is increasingly becoming more difficult to deal with serious environmental issues as population continues encroaching on the water catchments, forests, and marginal lands (Republic of Kenya 1997).

There is rising concern that rapid population growth, traditional forest clearing and shifting cultivation have resulted in fragmentation of forest despite the fact that traditional land use practices have maintained the ecological function of the River Tana in the past (Allison and Badjeck 2004).

Economic Causes

The economic root causes of modification of stream flow include economic growth in 1970s and 1980s and political

instability, market forces of demand and supply, poverty, taxes and subsidies, and governance.

Economic Growth

Economic growth alongside changes in the political environment within the East African Community (EAC) which did not guarantee continued supply of energy from the Owen falls of Uganda, led to increased demand for a more secure source. Hence, the seven forks hydroelectric power generation project was established in the River Tana. At present, the domestically generated electricity plays a key role in satisfying commercial energy needs in the cities and urban centres. So far, the hydroelectric power provides 72 percent of the domestically generated electricity (World Bank 2003). It is to be noted however that Kenya is not still self sufficient in domestic generated electricity and there are frequent unplanned power shortages (GOK 2003). Similarly, to meet the growing national food requirements, there is increasing attention on expansion of irrigated agriculture (GOK 2003). At the same time, the Kenya government has been faced with the challenge of achieving the desired high economic growth rate, and irrigation has been viewed as a means of boosting the agricultural productivity. The NIB's Mwea rice irrigation scheme, TARDA rice irrigation scheme, and the Bura and Hola cotton irrigation schemes were established along the River Tana by the government towards achieving the targets for agricultural sector growth. Even though these public irrigation schemes have become dormant with the exception of Mwea rice scheme, investments of various magnitudes have been established targeting the lucrative horticulture industry. This industry has in turn boosted the Kenyan economy through foreign exchange earnings, mainly derived from external export market opportunities. However, the current water usage rates are inefficient due to low fees where such fees exist. As a result, crops like rice, which require large volumes of water (flood irrigation techniques) are grown with a water wasting technique instead of promoting irrigation of water efficient crops.

Poverty

Poverty manifests itself in many forms in the Tana River basin. It can be seen in small-scale farmers eking for survival on small parcels of land that can hardly provide the necessary agricultural output for sustenance, town dwellers that live in informal settlements without basic provisions such as water and survive from hand to mouth mostly based on daily contractual odd jobs. Poverty includes inadequacy of income and deprivation of basic needs and rights, and lack of access to productive assets as well as to social infrastructure and markets.

The 1997 welfare monitoring survey in Kenya estimated the absolute poverty line at Ksh.1, 239 (USD 15) per person per month and Ksh.2, 648 (US D 33) for rural and urban areas respectively (Republic of Kenya 2003). Because of the dehumanizing conditions of extreme poverty, the United Nations in its millennium resolutions agreed to place every effort to free the poor out of poverty (United Nations 2000). Development assistance is therefore to be given to countries that are genuinely making an effort to apply their resources to poverty reduction. Today, about 60% of the population living within this subsystem lives below this poverty line. As a result, many people are forced to engage in unsustainable farming practices, encroach into the water catchments, indulge in excessive use of fuel wood, and engage in unsafe sewage disposal (Republic of Kenya 2001). These activities have negatively affected the environment making the survival difficult. So far, there is increased soil erosion with sediments being transported downstream where the impacts are severe. Consequently, this has also resulted in overexploitation of land and pollution of water resources. Water resources have been depleted, fuel wood exhausted and more time is now being spent to fetch these items from long distances.

Taxes and Subsidies

Even though the decision to invest in the generation of hydropower was driven by the changes in the political climate within the East African Community, the Kenya Government also saw this as an opportunity to generate the much needed revenue since the demand for power was guaranteed. As a result, the government gains through direct revenue paid to it as the leading shareholder and from the taxes collected from the corporation and users of electricity. The occasional provision of subsidies to the electricity generating company has also ensured sustained generation of hydropower. Currently, there are plans to expand hydropower generation in the river basin. This plan would only be implemented if the government of Kenya gives a subsidy to the Kenya Power Generation Company. The implementation of this plan would involve the establishment of new dams on the upper course of River Tana. One important site that has been identified for the construction of one more hydropower generation dam is at Mutonga/Grand Falls (Hirji et al. 1996; GOK 1979; GOK-TARDA 1982c). This may further impact adversely on the downstream communities.

Governance Causes

Poor Governance of Water Resources

Water resources in Kenya are managed under the Water Act of 2002 which deals with the conservation and controlled use of water resources. This Act provides for water-user rights which promote water abstraction for irrigation, domestic and industrial supplies. This legislation tackles issues pertaining to water resources management, water and sewerage development, and institutional framework and financing of the

sector. Since this legislation promotes abstraction of large volumes of water for irrigation and other uses, this abstraction adversely impacts the poor rural farmers, pastoralists, and downstream fishermen.

Also relevant to river and river-basin management is the Tana and Athi Rivers Development Authority Act (Cap 443), which provides for the establishment of the Tana and Athi Rivers Development Authority (TARDA) to advise on the institution and coordination of development projects in the Tana River and Athi River basins and related matters. This includes the planning and development of the two rivers' basins and resources. However, the legal status of estuaries and deltas remains controversial, as they cut across several jurisdictions (riparian, forest, marine, coastal zone) and harbor abundant resources. There is little effective legal protection except under protected-area or forest-reserve regulations. The 1971 Ramsar Convention could be a primary instrument for the conservation of these ecosystems at the national level. In this regard, an application for appropriate Ramsar designation of the Tana Delta is under preparation. On the other hand, all intertidal zones are public, meaning that no beaches in Kenya are privately owned. However there is no single or specific legal instrument that relates to beaches, representing a weakness in the law (Government of Kenya 2008).

Conclusions

Modification of the flow regime of River Tana has both negative and positive impacts. These socio-economic impacts include conflicts between agriculturalists and pastoralists due to limited dry season pasture and watering points that lead to influx of large herds of cattle at the river delta with the pastoralists occasionally letting their cattle graze on crops in the farms. This has often resulted in serious confrontations and deaths. Floodplain agriculture has also reduced due to retention of floodwater in hydroelectric dams that are located upstream. Reduction in floodplain agriculture may adversely impact on agricultural output and food security in the Tana River basin. Furthermore, communities that live downstream have reported noticeable decline in river size as well as sizes of ox-bow lakes. This has had negative impacts on fish production from the ox-bow lakes and it is expected that additional dam construction will rapidly exacerbate this decline in fishing area as well as fish landings.

The immediate causes of modification of the flow regime of River Tana were damming for hydroelectric power generation, and abstraction of water for irrigation and public water supply. Behind these immediate causes are six root-causes that have been classified in to three broad categories namely: demographic, economic and governance causes. The demographic causes include high population growth rate and urbanization whereas the economic causes include instability in economic growth, poverty, taxes and subsidies. Governance causes include poor resource allocation and inadequate enforcement of policies and legislations.

The multiple impacts of modification of stream flow have tremendous effects on the welfare of people and therefore need to be addressed. It is recommended that investments should be channeled towards water treatment programs for the population in this area. A more long term monitoring study is needed on the rainfall patterns and stream flows which should also be integrated with a total natural resource monitoring of the basin to come up with appropriate integrated resource management of the basin for sustainable utilization and management of water and land resources.

Although there have been efforts to provide piped water from rivers and boreholes to various communities, there is still disparity in the provision of water in the rural and urban areas, with the urban areas being better off than the rural areas. A more proactive approach is required to bring water closer to the rural communities and at an affordable price. The arid areas still remain the most significant source of beef and other livestock products hence there is need to provide water services to reduce conflicts with other demanding sectors especially competition for watering points.

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