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Environmental and hydrological implications of the development of multipurpose reservoirs in some catchments of Kenya: meeting Kenya's water demands by the year 2010

GEORGE S. ONGWENYI, SHADRACK M. KITHIIA, F. O. DENGA & P. O. ABWAO
Postgraduate Programme in Hydrology, Faculty of Science, Department of Geography, University of Nairobi, PO Box 30197, Nairobi, Kenya

Abstract As the population of Kenya increased from 5.4 million in 1948 to 8.6 million in 1962, and from 10.9 in 1969 to 15.3 in 1979, there has been a corresponding increase in demands for provision of food for her growing population. At present the population of Kenya is estimated at about 23 million and projected to reach a figure of 34 million by the year 2010. As the growth of population and its demands becomes too dynamic, natural resources (land and water inclusive) still remains static and thus the need for appropriate measures to meet these needs and demands. The development of multipurpose reservoirs is considered to be one of these measures and in particular meeting water needs and demands. In this paper both the hydrological and environmental implications of multipurpose dam construction is assessed with particular attention to both Tana and Athi river drainage basins. Environmental problems like silting of the dams and disease spreading are considered together with provision of water for domestic, rural and urban use, recreational purposes and irrigation. These are all geared towards proper utilization and assessment of the water resources in the said catchments and Kenya in general.

INTRODUCTION

Kenya has a total land area of 583 000 km^2 and her waters cover 111 230 km^2 which is equivalent to 19% of the total land area. Kenya has a mean annual rainfall of 621 mm which varies from under 200 mm in the arid areas in the north and east to over 2000 mm on the high mountain ranges. This amounts to over 322 770 million cubic metres of water. It relates to the rainfall variations and gives a very little idea of its effectiveness in both space and time.

The annual rainfall generally follows the seasonal pattern, and there are absolutely dry months from August through October in semiarid and arid lands. The seasonal variations described above are strongest east of the Rift valley, in the dry low lands of the north and east (with two distinct rainy seasons from March through May and from October through December). In the area West of the Rift valley the seasonal distribution of rainfall is weakest, with a long and almost continuous rainy season. Most of the rain falls from April to August; September and october are drier months and November is again with high rainfall. The variation of annual rainfall is considerable especially in the drier areas. Monthly rainfall is even less reliable than annual rainfall and total lack of rainfall or vast excesses are often experienced at representative rainfall stations.

Despite the fairly precise seasonality of the rainfall regime, all areas experience extreme variability, and especially so in the more arid areas. In considering natural water resource availability, it is necessary to take into account both the seasonality of the rainfall and its varying unreliability. In relating available water with rainfall, the hydrological cycle is of great significance. Rain water is at first intercepted by vegetation cover, some is lost through evaporation while the rest reaches the ground surface as drip or stem run from the vegetation. Evaporation further occurs from the ground surface, whilst the balance of the rainfall either infiltrates and becomes soil moisture, or runoff and becomes stream flow. The soil moisture is partly taken up by the vegetation and lost through evapotranspiration with remainder entering the water table from which it emerges as spring or base stream flow or goes to groundwater recharge. Some link exists between the groundwater and stream flow through intermittent movement with further evaporation from the latter. Eventually, the groundwater and the stream flow reach the sea or lakes or swamps and return to the atmosphere through evaporation.

Surface water (in streams, dams or lakes) is intercepted and removed by direct abstraction or by diversion via pipeline, pump and pipeline or by canal. Available of surface water is increased by the construction of dams to form reservoirs which help even out the variability in rainfall.

Groundwater is intercepted by digging a well or sinking a borehole and then abstracting the latter by direct or by mechanical means.

The Ministry of Water Development (MOWD) set up in 1974 is charged with the responsibility of collecting data for surface water assessment. The meteorological and hydrological networks allows reasonable estimates of the country's water resources. There are 923 hydrological stations that have been established. Only 43% of the total number are operational, the remaining 57% having been closed due to shortage of funds for the monitoring staff, manpower or stations having been resited. This fact means data regarding water resources in Kenya is meagre and to some extend unreliable. Thus, the need fro proper assessment of the waters in both the rivers and lakes as a prelude to multipurpose dam construction and as a means of alleviating the problem of water shortage in the country.

THE WATER RESOURCES OF KENYA

The development of water resources of any country (Kenya) is of prime importance for its economic growth. Thus, its prospecting and rational utilization is paramount in meeting its various uses and demands. Kenya's water resources of course, are among the most basic of all those available for speeding her development. Their productive use will mean more food, more power, more trade, better transport, greater job opportunities and improved health conditions. Uncontrolled flowing water is a major cause of human suffering and misery. Regulated and put to use, the same water is the very basis of life and development.

In Kenya, rainfall is the main source of surface runoff which amounts to a total of 37 000 million m^3 annually. Kenya receives an average annual rainfall of 621 mm amounting to 322 770 million cubic metres of water. This is however, not evenly distributed in the whole Kenya as discussed later in this paper. The total runoff amounts to approximately 11% of the mean annual rainfall, but of this approximately half is further lost through evaporation or percolation before reaching the permanent water courses or as channel loss. Total mean available runoff therefore amounts to about 6% of mean annual rainfall. Without the provision of any storage, only a small proportion of this is however usable. Where, usable unregulated runoff is that occurring as average flow during the three driest years in ten years then approximately 0.5% of the mean annual rainfall is in fact truly available (about 3 mm) without the provision of storage, that is some 1600 million m^3. With the provision of major storage and regulation of the major rivers together with extensive small storage on seasonal rivers might increase this by as much as a factor of 7 (approx. 11 300 million m^3). This suggests that perhaps 3.5% mean annual rainfall could become available for man's

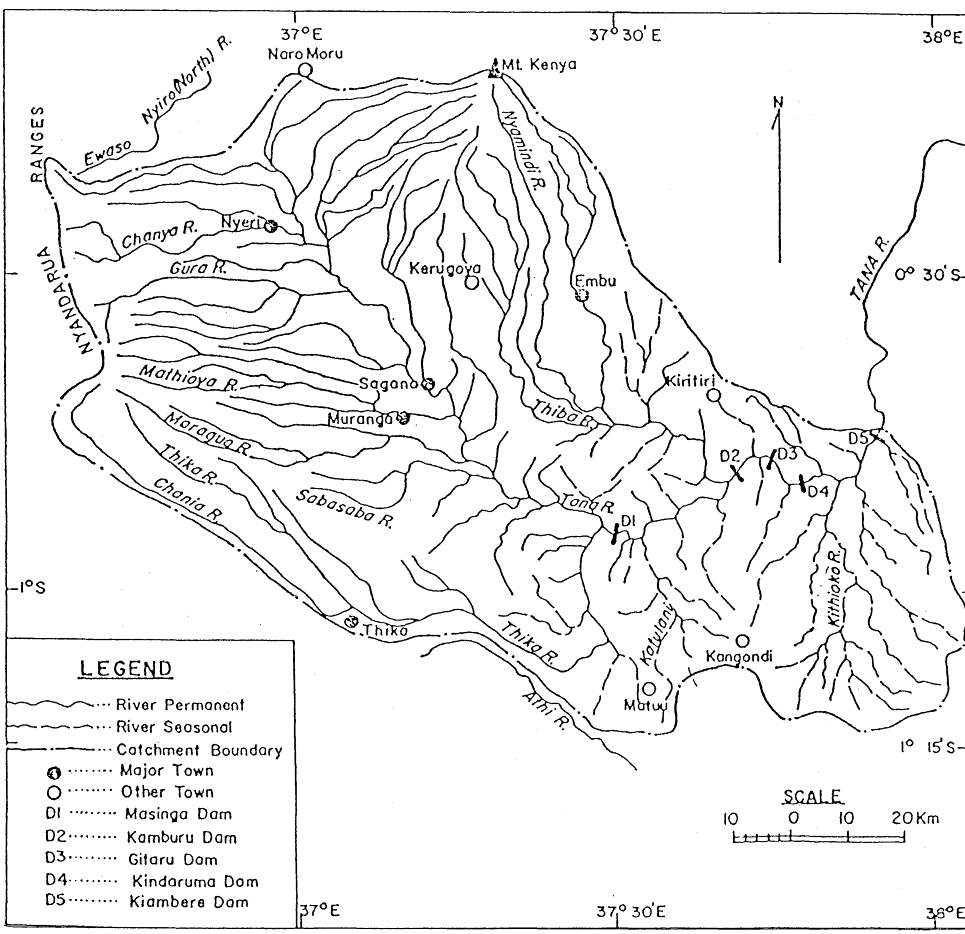

Fig. 1 River networks of the upper Tana basin.

use, say over 11 000 million m^3. Assuming such major storage were achievable by the year 2010 would provide approximately 1 m^3 per person per day to the people of Kenya from surface water source.

The surface drainage network in Kenya has been influenced by the volcanic and morphotectonic development of the landscape that has resulted from the formation of the Rift valley with an average width of 64 km. This means that from the highlands on the shoulders of the Rift valley water flows towards Lake Victoria and eastwards towards the Indian ocean. However, drainage network shows that the country falls into five major drainage areas as indicated in Fig. 1. About half of the total fresh surface water resources of the country is located in the Lake Victoria drainage area which covers only 8.4% of the total area of Kenya, while the Tana basin covering an area of about 23% of the country carries about one third of the total fresh surface water resources. This means that whereas Kenya may be said to have water, it is unevenly distributed. Indeed, this poses the problem of planning for the effective utilization and development of the country's water resources for various uses and in meeting its water demands by the year 2010. Topographic and other geologic barriers make it difficult for this water shortage experienced by people in the arid and semiarid parts of the republic covering close to two thirds of the total area of the country. This problem is compounded by the fact that there is not enough rainfall and no permanent rivers or streams are available in these areas.

Evapotranspiration which may reduce the effectiveness of rainfall and hence the water resources of the country are equally variable in that the arid and semiarid parts of the country experience the highest rates of evapotranspiration effectively taking away the little water available in these areas. The only cheap source of water in these areas for man and his livestock is the water emanating from the ground systems. The five drainage basins and their surface water quantities are depicted in Table 1.

Related to area and population, Kenya has a limited surface water resources with perennial rivers concentrated in the central and western areas. Therefore. the water resources of Kenya must be determined with sufficient accuracy for covering, developing and managing these sources efficiently. In view of the rapidly growing population expected to reach 37 000 000 by the year 2010, there will be even greater competitive use of water for domestic, rural, urban, irrigation, industrial, individual and agricultural requirements. Thus, the need for multipurpose reservoirs development for alleviation of water storage and increasing water supply in respect to demands.

THE HYDROLOGICAL ASPECTS OF THE TANA AND ATHI RIVERS

The Tana and Athi river drainage basins cover the most populated areas of Kenya and acts as the main sources of water for domestic, industrial and agricultural (both irrigation and livestock) uses. Rivers Tana and Athi make up the two drainage basins. These two rivers provide water for the largest irrigation schemes in the country, act as the main sources of urban water supplies (Nairobi city in particular) and harbours most of the hydropower reservoirs in the country. Thus, appropriate assessment and harnessing of the two rivers through further reservoir development, proper use of soil and water conservation techniques and reduced environmental degradation will enhance Kenya's policy of meeting her water needs and demands by the year 2010.

Table 1 surface water from the main streams in Kenya.

Drainage basin no.	Area (km^2)	River	Mean annual runoff (1 000 000 m^3)
1	49 000	Nzoia	1 920
		Yala	965
		Nyando	500
		Sondu	1 235
		Kuja-migori	870
		Others	1 800
		Sub-total	7 290
2	127 000	Melewa	187
		Gilgil	28
		Molo	39
		Perkera	125
		others	430*
		Sub-total	806
3	70 000	Athi	720
		Tsavo	138
		Njoro-Lumi	293
		Springs	
		others	113*
		Sub-total	1 294
4	132 000	Tana (Garissa)	4 700
5	205 000	Ewaso Nyiro (Archers post)	740
		Grand total	14 830

* Estimated

Source: MOWD data bank.

The Athi River covers a total drainage area of 70 000 km^2 and it is periodically subject to floods and droughts. The river experienced floods in 1961-1962, 1968 and 1977 which caused significant damage to property and human life. This flood water should also be harnessed for the rehabilitation of the arid areas. Other problems which have received less attention include: alkalinity, salinity, contamination and sedimentation. There is also the problem of pollution of streams passing through Nairobi. This is mainly due to inadequately treated sewage, illegal discharges to the storm drains, direct discharges in unsewered areas and frequent blockages in the sewers. In the middle reaches of the catchment groundwater is rather hard because of high concentrations of calcium, magnesium, carbonate, bicarbonate and sulphate. Total dissolved solids concentration is of the order of 4000 ppm. The water can be used for livestock. Pockets of good quality water are exploited for public supplies.

Sediment transport estimates from 1965 or earlier indicate that this basin lost 55 000 t annually, but current estimates show over 5 million tonnes. Soil erosion results from surface runoff in Machakos and Kitui Districts due to the destruction of vegetation for charcoal burning, poor cultivation methods and overgrazing. Recent efforts of building terraces, benches and dams to conserve soil and water in the two Districts should be strengthened and extended to reduce surface runoff.

The Tana River drainage basin covers a total area of 120 000 km^2 and receives an average annual rainfall of 562 mm. The Tana River has been harnessed to a greater extent than Kenya's other major arid watersheds. Along its course are the main hydropower reservoirs; namely Kindaruma, Kamburu, Masinga, Gitaru and Kiambere. In its upper reaches is the Sasumua dam from whose water Nairobi city is supplied.

In addition to alleviating the problem of water shortage, multipurpose reservoirs development are also linked with both hydrological and environmental problems which can enhance the problem of water shortage by reducing the lifespan of the reservoirs through siltation. The use of better soil and water conservation techniques, regulating the stream flows and better water abstraction methods ensures longer life of the reservoirs.

ENVIRONMENTAL AND HYDROLOGICAL IMPLICATIONS OF RESERVOIRS

Although Kenya has numerous permanent and seasonal rivers, only five of these are permanent (Tana, Athi, Nzoia, Yala and Mara). During the wet seasons, the rivers and streams and swollen and silt-laden indicating extensive soil erosion.

Several inland lakes exist in Kenya, nearly all the major ones are found in the Rift valley. With the exception of Lake Victoria, Lake Naivasha and Lake Baringo which have fresh water, Lake Turkana is brackish (slightly saline) and all other lakes are saline.

Water use in Kenya takes many different forms varying from traditional well supplies to modern irrigation systems and hydroelectric generation stations. The total water use at present is about 600 million m^3 per year (18% for domestic, 69% for agriculture and 13% for industry). The demand for water is expected to increase rapidly and it has been estimated that the total water use in Kenya will reach 2500 million m^3 per year by 2010. In order to meet the need and demands for water for her growing population, Kenya is faced with the challenge of developing the existing water resources.

The development of multipurpose reservoirs across the main rivers is considered in part as a means of meeting these challenges. These have however, been linked to other environmental problems, sedimentation in particular. Five dams have been constructed across the Tana River with the aim of generating electricity at Kindaruma, Masinga, Kamburu, Gitaru and Kiambere (Fig. 2). Masinga dam was built to eliminate the seasonal fluctuations of the level of the water in Kamburu reservoir, to permit steady power generation at capacity. Consultants for East Africa Power and Lighting

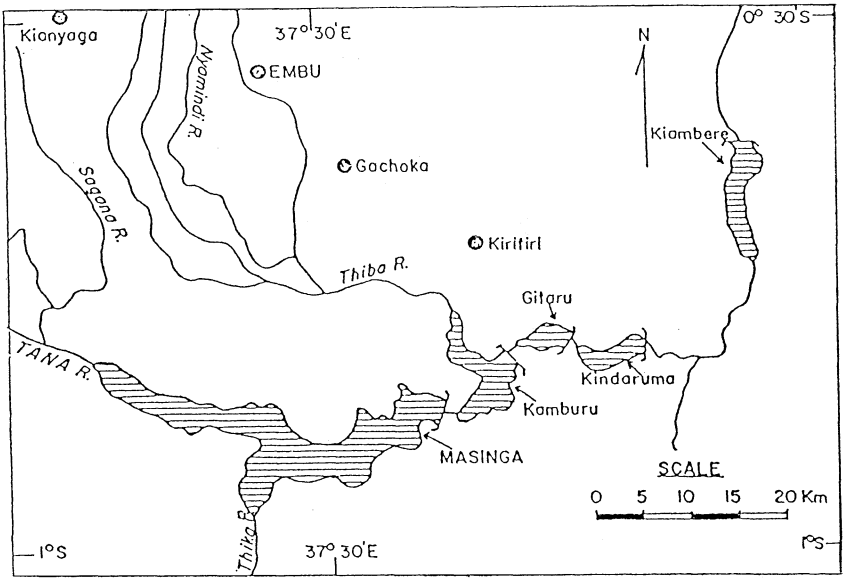

Fig. 2 Upper Tana's five major dams.

Company Limited (now Kenya Power and Lighting Company Limited) report that 12.6 million m^3 of sediment were deposited in Kindaruma reservoir since 1968. After 1971 Kamburu reservoir, above, trapped almost all the sediment. If the rate of sedimentation continues at Kamburu and Kindaruma reservoirs, generation of electricity would last less years than planned for. It will destroy fish and aquatic life of the lake and create flooding upstream.

Deforestation and land use changes associated with erosion have caused nutrient losses of top soil and productivity of land, as well as siltation in the reservoirs. These erosion processes have caused siltation in irrigation canals, at Mwea, where in 1977 the National Irrigation Board had to spend three million Kenya shillings to desilt the canals. Silt increases the turbidity of the water, rendering it unsuitable for many uses. Associated with the damage to vegetative cover (forest or grass) is a higher rate of runoff. In addition to removing soil, it raises peak flows, allows rivers to cut into fields, flood villages, and destroy irrigation inlets. It carries debris such as logs and branches which jam and cause serious local flooding. The greater runoff means infiltration of water into the soil, and tends to reduce stream baseflows, and may cause springs and streams to dry up in the dry season.

While some of the uses of a multipurpose project may be complementary, others may in fact be competitive. The intake for a drinking water supply, for instance, or the diversion structure for an irrigated system can often be located downstream from the hydro-station so that the energy in the water can first be used to generate electricity. On the other hand, the provision for flood control in a reservoir usually means reserving a considerable amount of storage to lop off flood peaks. This reduces the gross head on the turbine and hence reduces the power output. When streamflow regulation converts rivers to lakes or reservoirs, scenic values are changed, and reservoirs substantially increase evaporation from river systems, change water temperature, alter erosion around reservoir banks and trap sediment. Thus, if the full consequences of a new reservoir are to be weighed, they must place a socio-economic value on the resulting displacement of people, communicable disease hazards, the inundation of farm land, the enhanced potential for fish production and the modification of wildlife and agricultural production that was dependent on the previous existing river regime.

MEANS OF INCREASING WATER SUPPLIES TO MEET THESE DEMANDS

The increasing need for a optical utilization of the water resources in river calls for improvement of the availability of surface and groundwater for multipurpose uses. Reservoirs play an important role in regulating stream flow and thus facilitate its use, although they do not themselves constitute a major source of supply. The development of multipurpose reservoirs will assist in increasing water sources in the following manner:

(a) Storage of flood and excess water in the reservoirs and its release at time of high demand is the most practised measure to increase water available. However, the number of sites, suited for storage with economically justifiable solutions are limited: the main limitations being orographic and geological. In addition, the life time of reservoirs is in a great many cases reduced by silting as it was discussed earlier and diversion of the natural flow of the river remains in most cases the only practicable solution.

(b) In cases where the river flow cannot be regulated the availability of water can be improved by night storage in canals or small ponds. In case of irrigation where water is mostly utilised during day time, such night storage can double the amount of water utilised.

(c) Surface water used during the periods of good discharges and groundwater added during the low ware flow in the rivers. During floods excess water can be used for recharging the groundwater.

(d) In irrigation projects where surface is available in relatively short spates flood irrigation can be combined with tube-wells. The ground-water, led into basins, partly seeps into the ground, recharging the water table. Between or after spates, water stored underground in this way can be lifted from tube-wells and used for irrigation.

(e) Recycling of water used in towns and industries is another method to increase the availability of water. Utilization of sewage water or liquid measure of livestock farms for irrigation is another solution.

(f) Other measures of increasing water supplies include such techniques as watershed (catchment) management and the direct harvesting of precipitation. This is a cheap method and most practicable in the arid and semiarid areas of Kenya.

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