Assessment of Integrated Water Resources Management Practices in Gucha River Catchment

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Abstract
Gucha River catchment is one of the main rivers draining into Lake Victoria. The river is targeted for irrigation, power generation, domestic and industrial water use development in addition to serving a population estimated at 1,460,884 people. In this study, the assessment of water resources, water use water balance and the catchment status was done, in order to determine the implications of the IWRM practices on the catchment water resources. This was carried out through analysis of water resources data, stakeholder and community interviews, measurement of water quality parameters and physical observations on the catchment status.
From this study it was evident that policy and strategy which does not match the institutional capacities has resulted in deficient IWRM practices. From the study, the water resources in the catchment were estimated at 1,204 MCM/year, which is equivalent to 824 m^3/cap/year. It was also determined that in the advent of proposed developments, construction of water storage structures is required for sustainability of proposed developments. Study of six rainfall stations showed increase in rainfall trend in the upper catchment and decrease in the lower catchment. The Gucha River at RGS KB01A showed substantial increasing variability in the average and high flows with annual increase of 1.2 m3/sec and 21 m3/sec respectively. These observations allude to possible climate change effects and land use and catchment ecological condition changes. Effects of poor IWRM which include high river sediment load, estimated at 60 mg/ltr, river riparian encroachment, pollution and lack of data were observed and the study recommended development of adequate hydro-meteorological stations and information management system, human resource capacity development and review of the IWRM implementation strategy.

Key words: Gucha River Catchment, Integrated Water Resources Management, hydro-meteorological stations

1 INTRODUCTION

1.1 IWRM Concept

The International Association of Hydrologists publication No. 272 highlights one of the key elements in IWRM as the drawing up of a programme of measures envisaged necessary to prevent deterioration of the ecological quality and pollution of water resources in order to achieve good water status in all the water resources. One of the central aims in IWRM is to promote coordination and integration as a means of achieving more holistic water management and improving water resources sustainability (UNEP, 2012).

Biswas (2004) argues that the definition of IWRM does not define the parameters to be monitored in assessing the extent to which a water resources system is functioning in an integrated manner. He further explains that there are too many factors affecting WRM for successful integration to be achieved and states that this concept may not automatically make the water management processes and practices ideal and the applicability of IWRM and the impact of this concept on improving water management are not proven.

Numerous arguments regarding IWRM have been postulated. However as Hooper (2003) affirms, international endorsement of IWRM concept is seen at the highest levels, starting with the Mar del Plata UN conference in 1977, the Dublin Conference of 1992 and the Second (2000) and Third (2003) World Water Forums in Kyoto, Japan. IWRM theme recognized, inter alia, that the key issue confronting most countries today is that of effective governance, improved capacity and adequate financing to address the increasing challenge of satisfying human and environmental requirements for water. There is little documentation on the experiences in adoption of this IWRM approach in many developing countries and this paper presents a concise note on Gucha river WRM situation.

1.2 The Project Area and Study Approach

Gucha river catchment is one of the main basins that drain directly into Lake Victoria (Figure 1). The River is characterized by steep falls from the highlands, which are up to 2100 masl to relatively gentle slopes in the lower reaches which fall to 1143 masl. The climate in Gucha River catchment is influenced to some extent by the south easterly and north easterly monsoon and can be classified as modified equatorial climate. The relief effect of L.Victoria and the Kisii highlands substantially influence the climate in this region. The highlands area has rainfall of up to 2000mm, while the lower Gucha region rainfall is as low as 700mm annually.

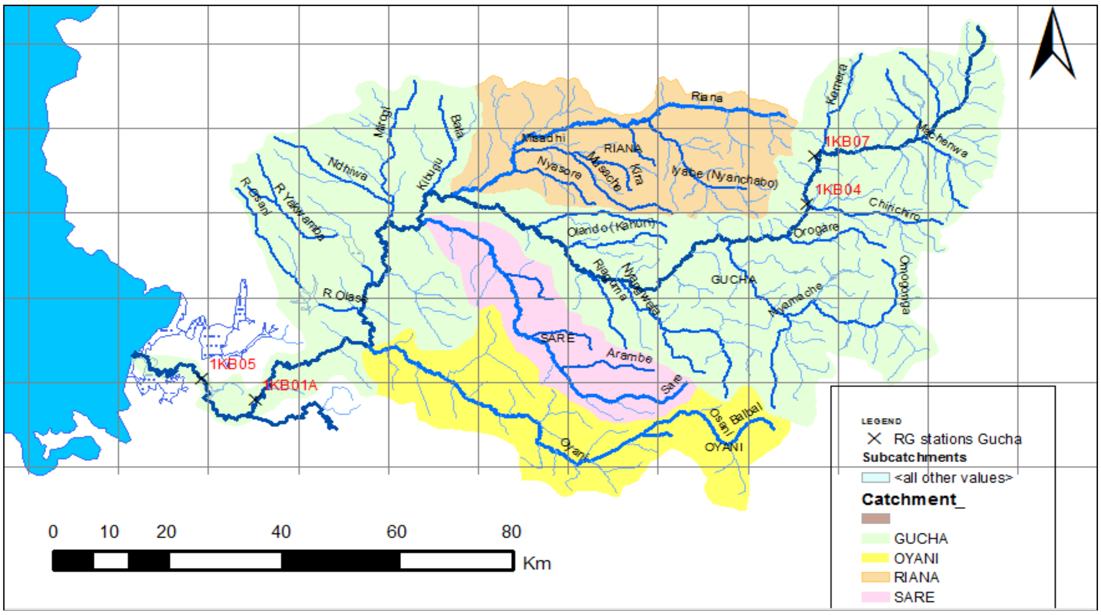


Figure 1: Gucha River catchment

In this study, the assessment of IWRM practices in the Gucha catchment was based on historical data on climate and water resources from various institutions mandated to collect this data. Data was also collected from interviews with various stakeholders, community survey and laboratory test of water quality of water samples collected from the Gucha River. Detailed assessment of water resources was done on Rain Water Harvesting (RWH) potential, stream flow, existing water supplies and water demand from which the water balance for the catchment was determined. Linkage between observation made in the catchment and the results of the diverse water resource data analysis were made to relate the WRM practices to the findings and establishment of gaps in IWRM practices in the catchment.

2 FINDINGS

2.1 Water Resources

i) Gucha River

Gucha River which is the spine of the catchment drainage system is about 167 km in length and covers about 2,006 km^2. The river has typical dentritic pattern which collects water mainly from the Chirichiro, Nyamache Kemera, Mugonga rivers and other lesser tributaries which add up to about 52 km/km^2 of tributaries. The furthest reach of all the tributaries are springs sources. Contribution to the stream flow however was mainly subterranean flow. There are three River Gauging Station (RGS) in the catchment; KB07, KB04 and KB01A. The most current data for stations KB07, KB04 was collected more than forty years ago and more than twenty year ago for KB01A. The assessment of expected data from these stations for the period data was available is shown in Figure 2.

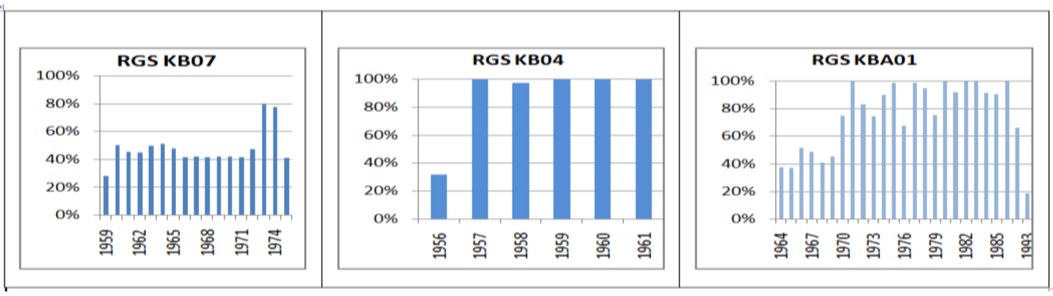


Figure 2: Data available for various years on RGS KBA01, KB07 and KB04

RGS KBA01 which is located at the downstream end of Gucha catchment was used in the assessment of the catchment water balance and was considered in detail. The average monthly stream flow at this station from the data available was estimated at 37.64 m^3/sec and the flow variation is shown in Figure 3.

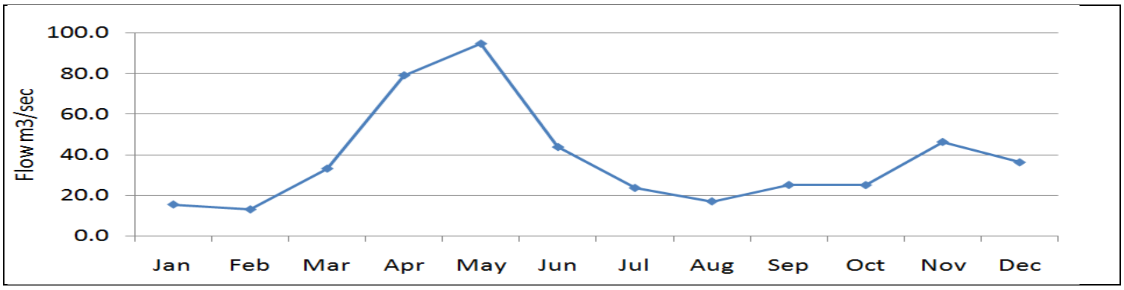


Figure 3: KB01A-Average monthly stream flow

From the analysis of high, average and low flows, Gucha river was found to have significant hydrologic variability between the years with a notable progressive increase in stream flow from 1964 to 1986 (Figure 4). The high flow increase at a rate 21.1 m^3/sec, the average flow at 1.2 m^3/sec and the low flow increasing at a rate of 0.2/ m^3/sec.

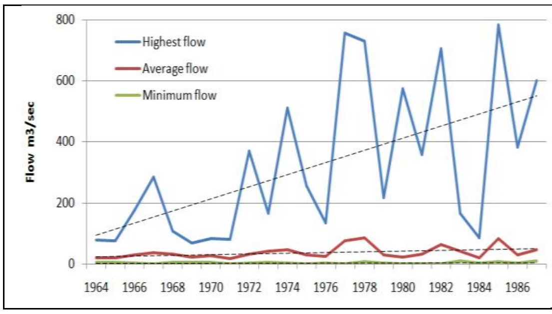


Figure 4: Maximum, average and minimum stream flows curves

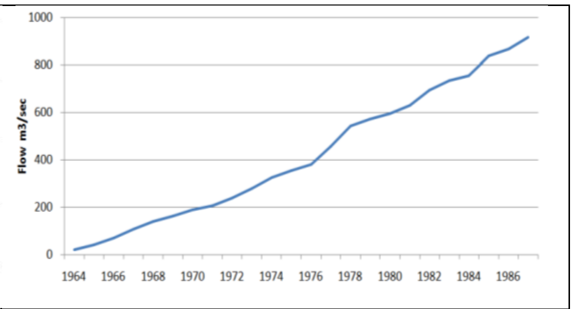


Figure 5: KB01A Cumulative average stream flow curves

The mass curve plot for cumulative sum of annual average stream flow indicates the data available for RGS KB01A is consistent (Figure 5). The corresponding rainfall or climatic data for the period the stream flow data was analysed (1964 to 1986) was not available and the data from the other gauging stations along the river was not sufficient to establish the flow trend along the Gucha River. It was also observed during the study that there have been substantial land use changes in the catchment as reflected in replacement of natural vegetation with farming. This could have the effect of increasing runoff and a reduction in the water percolation, which may explain the trend observed in Figure 5. The 80% probability low flow for Gucha River was estimated at 8.68 m^3/sec at KB01A.

ii) Other surface water resources

There are numerous springs in the upper and middle Gucha catchment, which are the sources of most of the rivers in the catchment. Water Resources Management Authority (WRMA) the agency responsible for WRM in the country did not have records on the springs which were estimated to be over 800 and the small dams and water pans observed particularly in the lower Gucha catchment. The water pans in the catchment were observed to have a capacity estimated at between 2,000 and 4,000 m^3 and the total storage capacity of the pans in the catchment was estimated at 90,000 m^3. It was estimated that about 50% of the water stored in the pans was lost through evaporation and seepage. It was also observed that well constructed and managed water pans resulted in improved ecology, vegetation and micro climate around the pans.

iii) Rain Water Harvesting (RWH)

There were ten rainfall stations in the catchment which were used in rainfall data analysis with data available for the period between 1965 and 2000. The rainfall trend in the stations in upper and lower catchment is presented in Figure 6 and Figure 7.

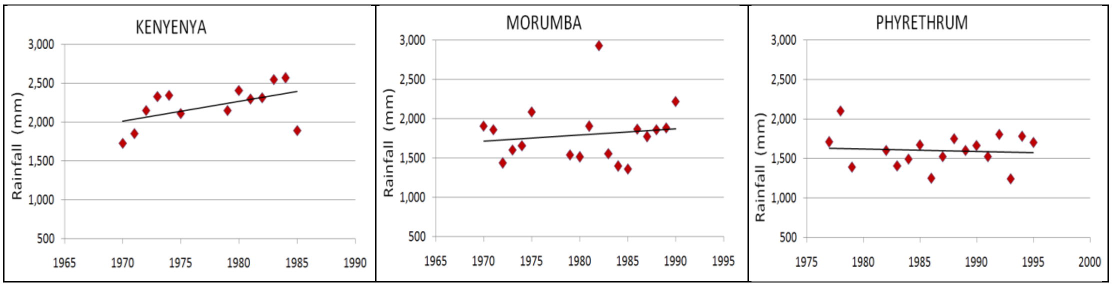


Figure 6: Rainfall trend in the upper Gucha catchment

The average annual rainfall in the upper catchment was observed to have a slightly increasing trend in Kenyenya and is relatively stable in Morumba and Pyrethrum stations between 1965 and 1995.

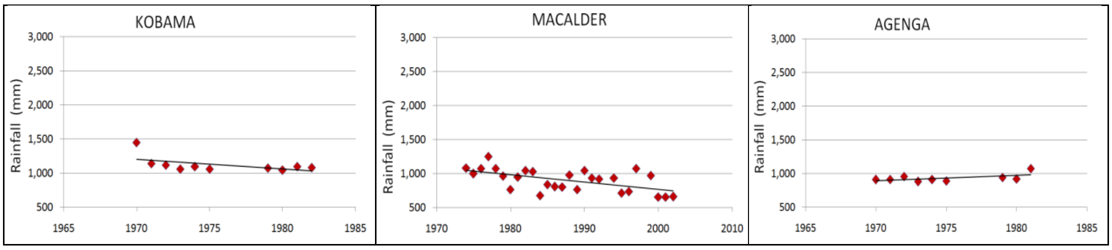


Figure 7: Rainfall trend in the lower Gucha catchment

The average annual rainfall in the lower catchment was observed to have reducing trend in Kobama and Macalder but a slight increasing trend in Agenga station (Figure 7). Change in rainfall pattern which is one of the keys indicators of climate change could have substantial impact water resources availability and quality in a catchment.

A time series analysis of the RWH was used to delineate three rain water harvesting potential zones based on basic rain water harvesting parameters, which are summarised in (Figure 8).

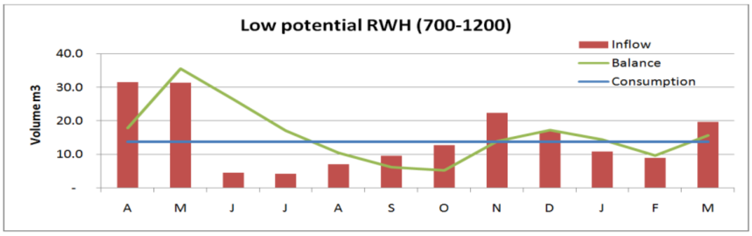
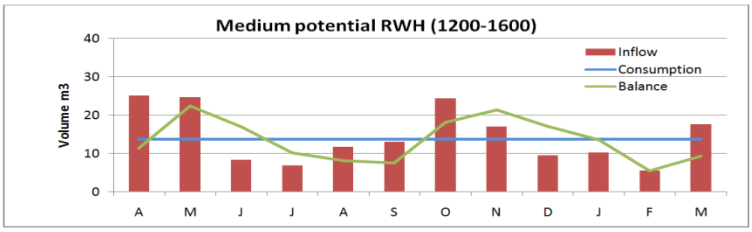
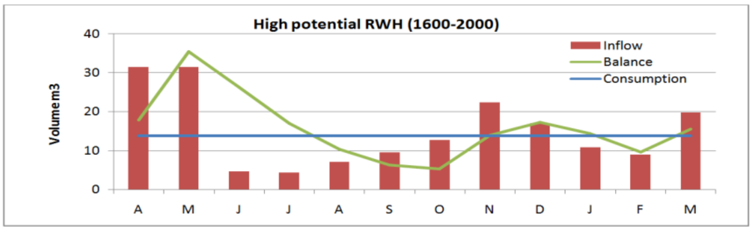
Zone and time series	Optimal parameters
	Storage required - 45 m^3 Optimal roof size - 195m^2
	Storage required - 30 m^3 Optimal roof size - 130 m^2
	Storage required - 25 m^3 Optimal roof size - 85 m^2

Figure 8: Time series for low, medium and high RWH zones

The analysis was determined based on a house hold water requirement of 460 l/day estimated from the community survey conducted during this study. The time series in Figure 8 shows that a system of combined roof and tank size ranging from 195 m^2 and 45 m^3 for low potential to 85m^2 and 25m^3 for the high potential areas would satisfy the domestic water requirement of the Gucha catchment. The delineated zones are shown in Figure 9.

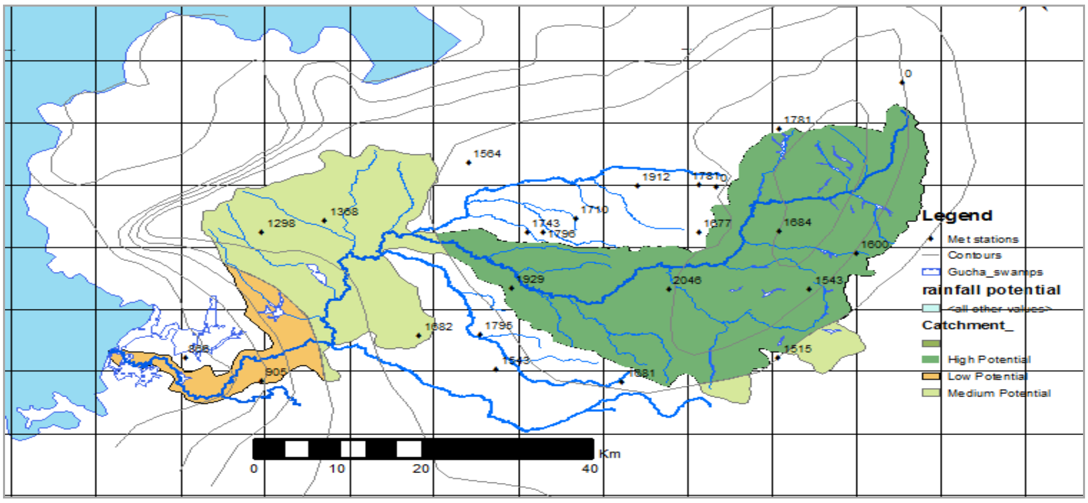


Figure 9: RWH potential zones

More that 90% of the catchment residents have galvanized iron sheet roofs which are ideal for RWH development. However less that 5% of the population effectively utilizes rain water, in spite of the low water supply coverage, indicating the need for effective RWH advocacy in the catchment.

iv) Ground water

There were many shallow wells in the upper and middle Gucha catchment, equipped with rope and bucket with depths ranging from five to ten meters. The lower Gucha had many wells equipped with hand pumps, which had depths ranging between ten and thirty meter. The WRMA offices did not have any information on shallow wells. The office also did not have updated records of the boreholes in the catchment. The limited records indicated the boreholes had yields ranging from 0.4 to 15m^3/hr. Ground water in the catchment was highly under exploited and accurate estimation of the ground water potential was therefore not possible.

v) Water Quality

There was no water quality data was available on water resources in the catchment from the concerned agencies. During this study, water samples were collected at pre-selected location (Figure 10) and tests on the physical water quality done. The samples collected in June 2012 were analysed for suspended solids, color, turbidity and conductivity. The results of the tests show progressive deterioration of the river physical water quality, from the source to the outfall (Figure 11).

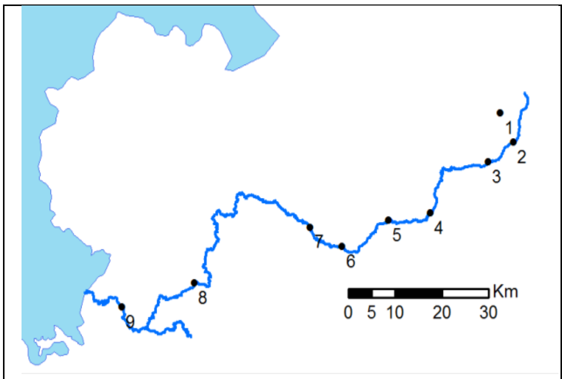


Figure 10: Location of water samples collected along Gucha River

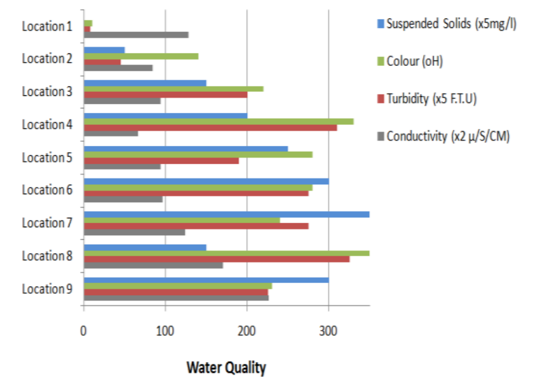


Figure 11: Water quality for the samples collected

The measured sediment load from the tested samples was estimated at 60mg/ltr. This translates to sediment transport of 191.8 tons per day based average flow (37.64 m^3/sec). The estimated amount of sediment transported by the river was quite low compared to the estimate made by Gibb (2011) study of 3,900 tons per day, indicating the sediment transported by the river during the rainy season was over twenty times the sediment transported during the dry season. Monitoring of sediment load transportation soil erosion and sediment management planning are important activities in IWRM which have not been given due attention in the catchment.

Gucha River was also found to be exposed to other forms of pollutions, which included human activity; mainly laundry and water fetching directly from the water sources, livestock watering directly from the river, effluent discharge from tea factories and Kisii town sewerage treatment work.

2.2 Water demand

The water demand assessment in the catchment was carried out for both the current water needs and for twenty years into the future (year 2033). Total catchment water demand excluding irrigation water use is shown in Table 2.1.1. .

Table 1: Summary of the catchment water demand excluding irrigation

User category	Water demand m3/day		
	2013	2023	2033
commercial	18,900	25,400	34,136
Industrial	10,000	13,439	18,061
Livestock	13,671	15,102	16,682
residential	129,765	174,393	234,370
Institutional	19,465	26,159	35,155
Total	191,801	254,493	338,404

From the demand analysis, the Gucha catchment water demand was set to increase from the current 191,801 m^3/day to 338,404 m^3/day in year 2033, which is a 76 % increase. With exclusion of irrigation water demand, Gucha catchment water demand distribution is shown in Figure 16. The figure shows that domestic water constitutes about 69% of the water demand while commercial and institution demand constitutes 20% of the demand.

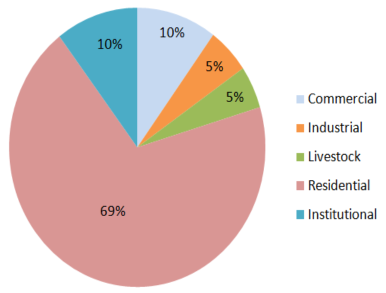


Figure 12: 2033 Water demand

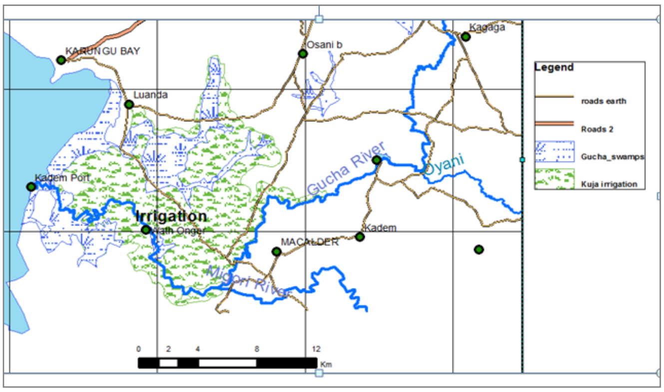


Figure 13: Location of Lower Kuja irrigation scheme

Lower Kuja irrigation scheme under the National Irrigation Board (NIB) which covers 7,717 Ha is currently under construction (Figure 13). The irrigation scheme design and proposed operation demonstrates an integrated approach to WRM in the following aspects:

- Incorporating flood protections infrastructure as part of the irrigation scheme;
- Carrying out market studies in the process of recommending appropriate crops to be cultivated;
- Allowing for other preferred economic activities by the community which include livestock farming;
- The entire project essentially seeks to improve the community's quality of life utilizing water as an economic resource: and
- An irrigation water users association has been constituted and structured training and capacity building of the members on appropriate farming methods is planned;

The summary of the Irrigation Water Requirements (IWR) for the Lower Kuja scheme is given in Table 2

Table 2: Summary of IWR for Lower Kuja Irrigation scheme

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigated area (Ha)	5,343	1085	5343	5343	6897	6897	3459	3459	3459	5343	4523	3205
Scheme IWR (m3/s)	3.2	0.9	1.5	0.8	3.0	9.2	5.2	5.4	5.3	2.1	1.9	4.3

The IWR for the scheme was determined assuming rainfall data from Agenga station and guidelines provided by Food and Agricultural Organisation (FAO).

2.3 Current water use

Water resources use in catchment and the reliability of these sources is summarised in Figure 14 and 15 respectively. Residents in the catchment used multiple water sources, due to inadequacy of their preferred water source, which was determined mainly by quality, proximity and availability.

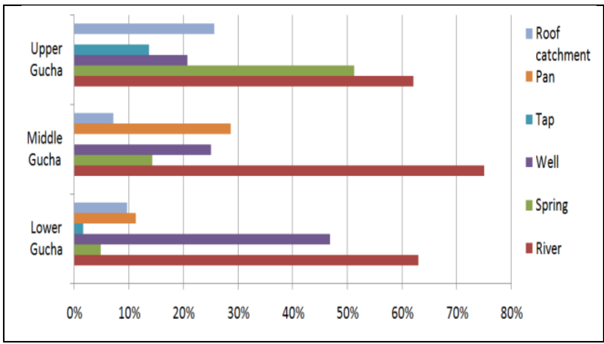


Figure 14: Water sources in the catchment

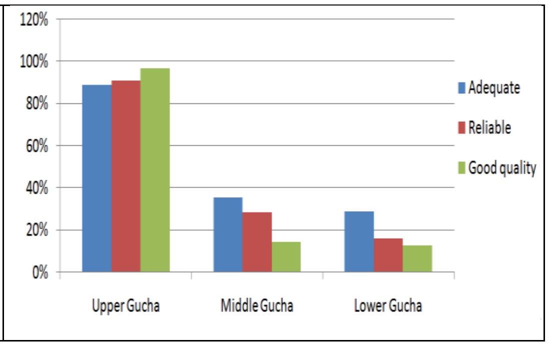


Figure 15: Summary of drinking water sources

There were only six piped water supplies with a total water supply capacity of 13,300m^3/day which supplied less than 7% of the water used in the catchment. The rest of the residents in the catchment collected their water directly from the water sources.

2.4 Water balance

The summary of water resources available, water demand (2033) and water balance at RGS KB01A are presented in Table 3. Based on the 80% low flow, the catchment was predicted to experience water deficits in the months of December, January, February and March by year 2030.

Table 3: Water balance (m3/sec)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water resources												
Gucha river	5.60	4.07	4.80	9.50	37.17	23.0	13.21	9.83	11.9	9.50	9.73	7.20
Ground water	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Piped water	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	***6.13***	***4.60***	***5.33***	***10.03***	***37.70***	***23.5***	***13.75***	***10.36***	***12.5***	***10.03***	***10.2***	***7.74***
Water Demand												
commercial	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Industrial	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Livestock	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
residential	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Institutional	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Irrigation	3.21	0.92	1.54	0.85	2.98	9.16	5.16	5.37	5.29	2.12	1.94	4.30
Oyani, Sare +	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Total	***7.13***	***4.84***	***5.46***	***4.76***	***6.90***	***13.0***	***9.08***	***9.28***	***9.21***	***6.03***	***5.85***	***8.22***
Water Balance	**-0.99**	**-0.24**	**-0.13**	**5.27**	**30.81**	**10.4**	**4.67**	**1.07**	**3.31**	**4.00**	**4.41**	**-0.48**

The above analysis shows construction of water storage structures is required to avoid eminent water deficits within the catchment in the future.

2.5 Water resources management

WRM in the country is the responsibility of WRMA, under the Ministry of Environment Water and Natural Resources (MEWNR). WRMA has a national office, regional and sub-regional offices. The national office is in charge of policy, national strategy, coordination and technical support to the regional offices. The regional office coordinates and provides technical support to the sub-regional offices and coordinates the Catchment Advisory Committees (CAC) which includes various stake holders. The sub-regional office for Gucha catchment located in Kisii, implements of all the physical interventions in Gucha River, Migori River and L. Victoria Southern shore streams through Water Resources User Associations (WRUAs), which are community based organization formed for purposes of managing water resources in their areas. The general findings from this study on the WRM at the catchment level were:

- Minimal data had been collected on water resources in the last twenty years;
- There were no any functioning river gauging stations in the catchment;

- Five WRUAs were active in the catchment;
- There was scanty catchment improvement interventions by the WRUAs;
- Records on water abstraction permits in the catchment were not updated;
- There was no analysis of water resources in the catchment done, the regional office also did not have capacity to carry out the analysis;
- WRUAs capacity building and sub-catchment management plans for part of Gucha catchment had been prepared with assistance from WRMA staff. No funds have however been availed for implementation of the proposed plans by the WRUAs; and
- There was no correlation between the proposed activities in the sub-catchment management plans with implications on the water resources.

2.6 Stakeholders participation in IWRM

The key stakeholders in IWRM in Gucha River catchment include MEWNR, Ministry of Agriculture (MoA), National Environmental and Management Authority (NEMA) and Kenya Forest Services (KFS) and Kenya Tea Development Authority (KTDA). Interviews held with representatives from these institutions informed that; there was a good understanding of IWRM approach, but there was limited participation by the stakeholders in WRM. The offices of the key stakeholders were under staffed and not able to undertake their core mandate, even without involvement in WRM. There were numerous cross cutting functions which were not coordinated across the various stakeholders which included soil conservation and improvement of farming practices by MOA, management of forest areas by KFS, and environment protection against pollution by NEMA.

2.7 Economic activities and WRM

One of the key principles of IWRM is integration of economic activities in WRM. Although the catchment is well endowed with water resources, there was however limited utilization of the water resources for socio-economic benefits, in areas like fish farming, irrigation and rain water harvesting. The positive environmental benefits the fish ponds and water pans used mainly for livestock watering, in term of the improved micro climate and enhanced aquatic ecology was noted as an incidental benefit from these activities which is not supported by WRM agencies. Agro-forestry practiced in the upper Gucha comprised of mainly eucalyptus tree farming along the river banks. It was noted that the trees have a positive impact of limiting soil erosion, but also had high water consumption and in some cases depleting the stream flows substantially.

3 CONCLUSIONS

IWRM is approach used in Gucha river catchment with WRMA as the lead agency. The implementation of IWRM approach was found to have fundamental challenges, which were evident from the numerous gaps in WRM identified in this study. There were no functional river gauging stations in the entire catchment and collection of climatic data was mainly dependent on the good will of the private owners of these stations. There was no hydrological data collection or scientific water resources data analysis, for information or decision making undertaken by the agency responsible for WRM. WRMA has various activities planned for implementation by WRUAs for catchment ecological improvement. The outcomes of these activities have not been correlated with the impacts water resources.

This study recommended development of modern hydro- meteorological monitoring system and an effective water resources management information system. Review of the current IWRM strategy in line with the available finances and stakeholders' capacity and expected outcomes, which should also have an effective monitoring and evaluation system, should also be done. There was notable water resources seasonal and annual variability in the catchment and water resources deficit is foreseeable in the future. The study recommended further investigations on the cause of this variability to enable corrective measures to be put in place and also recommended urgent development of dam structures to be undertaken. All the IWRM activities are tied to financial resources, which the Government and other agencies involved in the water sector should also urgently consider increasing.

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