Journal of Agri-Food and Applied Sciences
Available online at jaas.blue-ap.org
©2014 JAAS Journal. Vol. 2(4), pp. 113-123, 30 April, 2014
E-ISSN: 2311-6730

The Contribution of Community Water Management Systems to Enhanced Water Security under Changing Legal and Weather Conditions in Kenya

James Maina Mathenge* , Cush Ngonzo Luwesi, Chris Allan Shisanya, Ishmail Mahiri, Rose Adhiambo Akombo, Mary Nyawira Mutiso

Department of Geography, Kenyatta University; PO Box 43 844 00100 Nairobi

Corresponding Author: James Maina Mathenge

Received: 25 March, 2014 *Accepted: 12 April, 2014* *Published: 30 April, 2014*

A B S T R A C T

Since the implementation of the water sector reforms in Kenya in 2006, Ngaciuma-Kinyaritha catchment of Mount Kenya Region has seen the emergence of a Water Resource Users' Association (WRUA) amid dozens of Water Service Providers (WSPs) and hundreds of Community Water Management Systems (CWMSs). These new legal institutions were mandated to enhance water security through good management of the catchment's land and water resources and provision of adequate water services to all the stakeholders with their participation in water resources management. This study sought to assess the status of the water balance and security in Ngaciuma-Kinyaritha Catchment prior and after the establishment of a WRUA therein. This would thus elicit the contribution of CWMSs to water security in Ngaciuma- Kinyaritha under changing legal and climatic environments. For that purpose, the study used descriptive statistics, OLS regression and hydrological modelling to compute the streamflow, water demand and balance from 1990 to 2012, and predict the future water security from 2013 to 2035 under the NOR scenario (normal weather conditions), XLOSS scenario (flooding) and XSCAR scenario (drought) using BasinIT software, SPSS and MS Excel spreadsheets. Most of the results were pointing out to water shortages in Ngaciuma-Kinyaritha from 1993 and onward, generally without enforcement of an Ecological Base Flow (EBF) of 30% by the WRMA. There is therefore need for contingency plans to curb unexpected drought, which should be implemented by the WRUA with participation of existing CWMSs. However, further attribution studies are needed to explain the failure or success of the new legal institutions mandated to manage and supply water in Ngaciuma-Kinyaritha, namely WRMA, WRUA and WSPs

Keywords: *Catchment Degradation, Catchment Rehabilitation, Climate Change, Community Water Management System, Self-help groups, Stream flow, Water Balance.*

INTRODUCTION

The history of water services provision by communal self-help groups in Kenya is a long one. Njonjo and Lane (2002) explain that community involvement in the management of water resources and provision of water services can be traced back to the 1980s, when the government acknowledged local initiatives and by-laws that were taking place in rural areas to improve the supply and management of water resources (Van Koppen, 2007). This was strengthened by *harambee,* a slogan introduced at independence, sounding as the local spirit of working together to solve problems, and which has persisted as a means of mobilising collective action today. The number of Community Water Management Systems (CWMSs) has increased over the years, especially in rural areas. It is estimated that by 2000, 30% of the 8 million people in rural Kenya with have access to improved water through small schemes managed by community water supply systems (Ngigi and Macharia, 2007). In Western

Kenya for instance, 40% of villagers named "improved water management" as one of their top three priorities, thus providing an indication of the determination of community members to ensure their water security through effective management of their rural water resources (Shisanya and Kwena, 2005; Swallow, 2005).

The concept of community involvement in water management has regained popularity more recently, owing to the achievement of the Millennium Development Goals (MDGs), especially the one dealing with sustainable supply of water and sanitation services to all (Nishimoto, 2003). The latter recommends a holistic approach to governments and their citizens to achieve sustainability toward the management of their natural resources through Integrated Water Resources Management (IWRM). "IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000). The demand for coordinated management of water resources is justified by the multitude of human interests and natural ecosystems' needs (Agwata, 2006). If water demand by human beings for their land use activities is to be satisfied by the in-stream flow, an Ecological Flow Reserve (EFR) is equally needed to enable local ecosystems and their biological sub-systems to germinate and sustain this streamflow (Mogaka, 2006). Otherwise, climate variability and the unsustainable management of water resources would lead to both water crises and an ecological disaster (van Aalst, 2006; Luwesi, 2012). This has been the case in Kenya, prior the water sector reforms initiated in 1999 and which culminated with the release of the Water Act 2002 (Republic of Kenya, 2002).

These reforms were justified by the fact that Kenya receives less than 650 cubic meters of freshwater per capita, making it one of the most water scarce countries in Africa and the world (WRI, 2003). Moreover, water crises in Kenya were not due to the little endowment in rainfall but by ill policies and management practices (Lankford, 2004; Lelo, 2005). Although the country experiences high rainfall variability, the water sector in Kenya is characterised by low investment and extensive degradation of existing resources (Were, 2006). Inadequate access to safe and sufficient water presents enormous challenges as only approximately 12% of rural Kenyans have household water connections, and approximately two-thirds of poor rural households depend on unprotected sources of water-wells, rivers, lakes, ponds and rainwater (WHO and UNICEF, 2004; Katui-Katua, 2004). Many dams and reservoirs are silted up years before their designed lifespan, thus leading water scarcity and shortages in some parts of the country. The increasing siltation and depleting dams' volumetric storage capacity mostly arouse from the lack of investments in both infrastructure and catchment and aquifer management (Mumma, 2011). Thus, it is widely accepted that the implementation of IWRM influences the quality and reliability of water resources in a catchment area. IWRM is in fact is a tool for prevention of potential conflicts between economic growth, leisure and social welfare, and the conservation of ecosystems (Ayling and Kelly, 1997; Bower, 2003). Though not formally recognized, CWMSs have ever implemented IWRM to solve their water problems; they have equally used useful frameworks for action that acknowledge the complex human-environment interactions and feedbacks in the water system (Hirsch, 1999; Calder, 2005; Malzbender, 2005). It is therefore believed that their interventions on the ground holistically address the depleting streamflow and aquifer storage as well as ecological degradation issues at a river basin scale. Most important, they tend to link "upland catchment management" with downstream water supply, as expressed in the above definition of IWRM by the Global Water Partnership (GWP).

However, since the release of the Water Act 2002, the role and mandate of CWMSs are silent in the new legislations. The new water act recognises institutions mandated to only: (1) manage water resources; (2) provide water services; (3) administer and regulate daily water resources management and water services provision; and (4) make policies on sustainable water security in the whole country. Hence, the legal and institutional frameworks detailed in the Kenya Water Act 2002 include (1) Water Resource Users Associations (WRUAs); (2) Water Services Providers (WSPs); (3) Water Resources Management Authority (WRMA), Water Services Regulatory Boards (WSRBs), Catchment Areas Advisory Committees (CAACs), and Water Appeal Boards (WABs); and (4) the Ministry of Water and Irrigation (MWI). In this framework, community water is supplied by regulated WSPs and water resources management by recognized WRUAs, thus excluding CWMSs among the two categories.

Yet, some communities informally own certain organizations usually known as "Self-help" groups. In the rural areas, where private WSPs are likely to be few, the role of these CWMSs in the provision of water services and management of water resources is likely to remain significant. But how have these CWMSs guided the management and utilization of the water resources 2002 in Ngaciuma-Kinyaritha Catchment, to serve both domestic and irrigation purposes prior the enforcement of the new legal frameworks? What would be their contribution in IWRM under changing legal and climatic conditions? These questions and others are the main subjects of this study dealing with the contribution of CWMSs in balancing water supply and demand in Ngaciuma-Kinyaritha Catchment to mitigate the risk of deadly conflicts for water appropriation (Shaftoe, 1993; Ramírez, 1999). The study aims at assessing the contribution of CWMSs to domestic water security under changing legal and climatic conditions in Mount Kenya Region. Specifically, it intends to: (1) compute the streamflow, water demand and water balance in the selected catchment before and after the implementation of the Water Act 2002; and (2) predict the status of water security in Ngaciuma-Kinyaritha by the year 2035. The following sections present the materials and methods used in the study, as well as key findings arising from the analysis and their discussion.

MATERIALS AND METHODS

GEOGRAPHICAL SETTING OF THE STUDY AREA

Ngaciuma-Kinyaritha is a sub-catchment of the Tana River emanating from the Mount Kenya Region. The latter is a water tower made of four main basins: Athi, Ewaso-nyiro, Tana and catchments. Ngaciuma-Kinyaritha covers an area of 167 km^2, with a population estimated to about 65,000 in 2009, representing a density of 390 persons/km^2 (KNBS, 2010). The catchment is mainly located around Meru Municipality, in Imenti North District of Eastern Province of Kenya. The catchment is geographically bound by latitudes 37.5º E and 37.75º E, and 0.04º N and 0.15º N (Fig. 1). The catchment area is mainly dominated by undulating terrains highly dissected by streams and with altitudes ranging from 1120 m to 2600 m. Kinyaritha is the major river, which drains in Kathita. Its tributaries include Ngaciuma, Kambakia and Gachiege.

Altitudes in the catchment range from 2600 m down to 1120 m, and the soils are geologically young, except for the forested parts. The catchment is dominated by basaltic volcanic rocks with volcanic tuffs and pyroclasts of Nyambeni eruption of the Pleistoscene. There results in poorly consolidated soils that are susceptible to erosion and mass movement, as well as to high infiltration and seepage rates, especially on hillslopes (Förch, 2008). This justifies the little or no significant permanent surface drainage in the upper catchment area, with exception of Lake Nkunga crater that is fed by three springs and has a sub-surface outlet.

Climatic conditions in Ngaciuma-kinyaritha range from humid to semi-humid with mean annual rainfall estimated from about 1100 mm (in the lower zone) to 1600 mm (in the upper zone), with an average of 1315 mm, and annual temperatures ranging from 10o C to 30oC. The catchment lies under three coffee agro-ecological zones (AEZ), namely the Upper Midland AEZ 1 (UM 1) or the coffee-tea zone; the Upper Midland AEZ 2 (UM 2), which is the main coffee zone; and, the Upper Midland AEZ 3 (UM 3), the marginal coffee zone (Jaetzold, 2007).

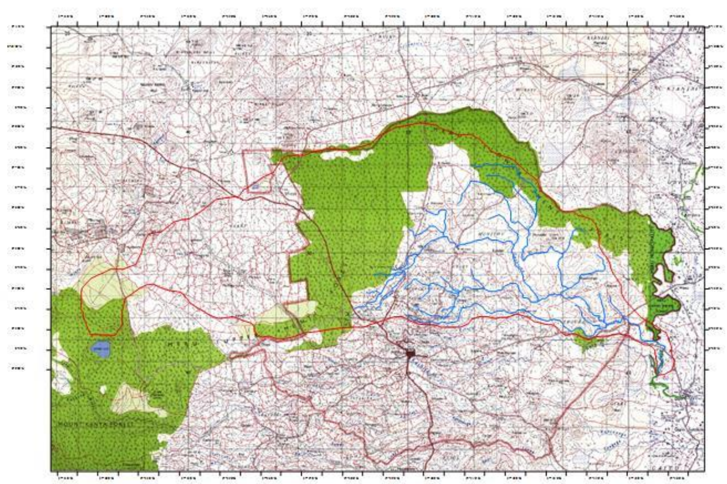

Figure 1. Map of the Ngaciuma-Kinyaritha Catchment (Förch et al., 2007)

Socio-economic activities are dominated by farming for both subsistence and commercial purposes. Subsistence farming includes bananas, maize, beans, potatoes, yams, arrow roots, sweet potatoes, finger millet, peas, cowpeas, sugarcane, and a wide variety of fruits and horticultural crops. Commercial farming involves the cultivation of horticultural crops, macadamia nuts, coffee and fruits. Lumbering is another source of income where trees such as eucalyptus, cypress and grevillea and other indigenous trees are grown for timber and firewood. The demand for more firewood coupled with the demographic pressure and economic activities have contributed to the reduction of the forest cover from 37% to 24% between 1987 and 2000, and to the depletion of wildlife in the forest reserve (Förch, 2008).

Apart from Meru town, which is the major commercial centre in the catchment, small market places include Gitimene (Naari), Muruguma, Kienderu, Chugu, Kauthene, Rwanyange, Ndiine, and Mugeene. These market centres are connected by earth roads, which are often affected by roadside erosions, gullies and other complications due to water disasters. The major tarmac roads traverse the catchment, namely Meru-Maua and Meru-Nanyuki.

RESEACH METHODOLOGY

Ngaciuma-kinyaritha Catchment was purposely selected owing to the fact that it was among the pilot catchments selected by the WRMA for rehabilitation, and which saw the emergence ofone of the first WRUAs of Kenya in the year 2006. Data collection encompassed primary and secondary physical data. Primary data were mainly collected during a hydrological survey, while a documentary review assisted to gather secondary data on rainfall, temperatures and river discharge within 3 major nodes of the catchment, namely Ngaciuma, Kinyaritha Minor and Kinyaritha Major. Other physical and computational data were collected using GPS, photographic devices, satellite images and topographic maps. These secondary data were collected from libraries and the internet, mainly from the Kenya Meteorological Department (KMD), the Water Resource Management Authority (WRMA), Ngaciuma-Kinyaritha Water Resource Users' Association (NGAKINYA WRUA) and other bodies of the Ministry of Water and Irrigation (MWI).

Data collected enabled the development of a database in SPSS and MS Excel spreadsheets as well as BasinIT hydrological system. MS Excel/ SPSS hydro-meteorological survey files displayed 3 times 43 time series of secondary data on temperature, rainfall and discharge secondary data from 1965 to 2012. The BasinIT model contained 3 demand nodes and 3 tributaries for Ngaciuma, Kinyaritha Minor and Kinyaritha Major.

Data analysis included data pre-processing, processing and results Interpretation. They were dealt with descriptive statistics, Ordinary Least Square (OLS) regression and hydrologic modelling to estimate streamflow, water demand and water balance in Ngaciuma-Kinyaritha Catchment using the Statistical Package for Social Science (SPSS), MS Excel and the BasinIT planning tool. Prior to proceeding to the actual analysis, data were pre-processed by activating Data View and Variable View spreadsheets in SPSS and data input in MS Excel and BasinIT spreadsheets. This was followed by the coding of information and data entry into files. Once finish, data outliers, mistakes and errors were checked, identified and cleaned. Finally, the assessment of the overall quality of the dataset concluded this quantitative data analysis.

The processing mainly involved the prediction of water balance in Ngaciuma-Kinyaritha through forecast of the streamflow and water demand in the catchment. Naturally, descriptive and inferential statistics were used to establish frequencies, means, crosstabulations and the F-value of a one-way Analysis of Variance (ANOVA). The study adopted the UBC (University of British Columbia) water balance flow chart designed by Shakya (2001). It presented the streamflow as a result of soil moisture balance computations (Rainfall contributions minus Infiltration control losses and Runoff allocation). The catchment was divided into bands. Specific water balance at each band depends on elevation which govern the distribution of runoff response (as surface runoff, inter-flow and deep groundwater flow). The generated streamflow was a result of the streamflow modification by the introduction of water storage and distribution logistics. According to priorities set on water based runoffs, the water storage system aimed to make water always available for domestic, institutional and industrial uses, as well as livestock and irrigation, to reduce water losses supplementation and increase groundwater replenishment to make the whole catchment wetter (Fig. 2).

The present and future status of water security in Ngaciuma-Kinyaritha was predicted as the potential water balance at each sub-catchment (Ngaciuma, Kinyaritha Minor and Major) using the Interactive Tool for Basin Water Planning (BasinIT) by the World Bank Institute (World Bank, 2009). First, an assessment of water resources available on the surface and underground in Ngaciuma-Kinyaritha Catchment and their different uses was conducted for the current year 2012 based on a hydrological survey and using the procedure suggested by Förch, (2008). Then projections for the period 1990-2012 (past) and 2013-2035 (future) were done in accordance with the linear programming technique used in BasinIT software package. The future water resources and demands were simulated under three assumptions: (i) " water availability under normal weather conditions" (NOR), based on the rainfall turnover of April 2012; (ii) "water scarcity under extreme weather conditions or drought" (XSCAR), based on the rainfall turnover of November 2009, and; (iii) "water loss under extreme weather conditions or flooding" (XLOSS), based on the rainfall turnover of December 1990. Finally, the status of water balance in the selected catchment was discussed under hypothesized "Ecological Base Flow" (EBF) and without an EBF to build scenarios of water security. This would enable the design of contingency plans under risk and uncertainty considering the above three (3) plausible scenarios. The predicted water balance, demand and supply would be assessed against options of catchment conservation taken by each actor, namely MEWASS, NGAKINYA WRUA and CWMSs, to unveil their contributions on water resource availability and sustainability in Ngaciuma-Kinyaritha Catchment

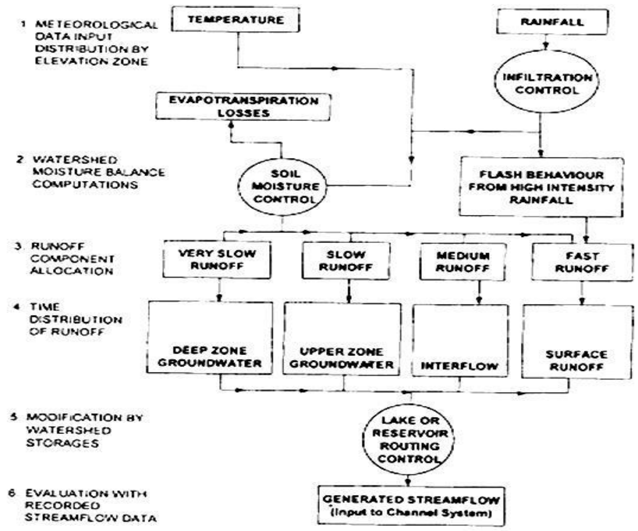

Figure 2. Water balance flow chart (Shakya, 2001)

RESULTS AND DISCUSSION

This section presents and discusses findings on the prediction of the water balance and security in Ngaciuma-Kinaritha Catchment for the period 1990-2035 (base year =2012). It first displays findings of the status of the water balance in Ngaciuma-Kinyaritha before and after 2002. Then a projection of the future water balance is provided under three scenarios, namely: (i) under normal weather conditions (NOR scenario); (ii) extreme flooding weather conditions (XLOSS scenario); (iii) extreme dry conditions (XSCAR scenario).

KEY FINDINGS OF THE STUDY

Current and Past Status of Water Balance in Ngaciuma-Kinyaritha (1990-2012)

(1) Status of Water Resources (1992-2012)

The potential groundwater yield in the year 2012 for Ngaciuma-Kinyaritha Catchment amounted to 262,800 m^3 and was estimated on the basis of an exponential function (b = - 0.004; R^2=.865; t = 0, 2012). The total streamflow for Ngaciuma-Kinyaritha rose up to 9,460,800 m^3, thus generating total water resources of 9,723,600 m^3. Table 1 shows rating curves for streamflows of the 3 main tributaries of Ngaciuma-Kinyaritha for the period 1990-2012, namely Ngaciuma, Kinyaritha Minor and Kinyaritha Major, while Fig. 3 illustrates their flow duration.

Table 1. Prediction of Ngaciuma-Kinyaritha Discharge (1990-2012)

River discharge	*Variables*	*Unstandardized Coefficients*		*Standardized Coefficients*		
		B	Std. Error	Beta	t	Sig.
Ngaciuma (Power Fit; R^2= 0.994; n=23)	ln(Adj_GHT)	2.161	0.009	0.997	253.492	0.000
	Constant	0.668	0.006		109.686	0.000
Kinyaritha Minor (Power Fit; R^2= 0.998; n=23)	ln(Adj_GHT)	2.460	0.006	0.999	441.881	0.000
	Constant	1.347	0.007		194.218	0.000
Kinyaritha Major (Power Fit; R^2 = 0.841; n=23)	ln(Adj_GHT)	-0.285	0.006	-0.917	-46.024	0.000
	Constant	-	-	-	-	-

Fig. 3 shows that only 35% of the total flow of the catchment lies between 1 and 2 m^3/s; the remaining 65% is below 1 m^3/s, with an average of 0.53 m^3/s , Ngaciuma contributing around 22.5% of the flow (R^2 = 0.994), Kinyaritha-Minor 32.5% (R^2 = 0.998) and Kinyaritha-Major 45% (R^2 = 0.841). Regarding the behaviour of these three streams, Fig. 4 indicates that the two Kinyaritha streams peak up in from January to March and fall down from September to December. However, Ngaciuma flow naturally increases during the long rainy season (from March to May) and the short rainy season (from October to December) while constantly decreasing during the long dry season (from June to September) and the short dry season (from

January to February). These patterns of river discharge confirm the fact that Ngaciuma stream relies mainly on rainfall while Kinyaritha streams benefit from permanent springs existing in the catchment.

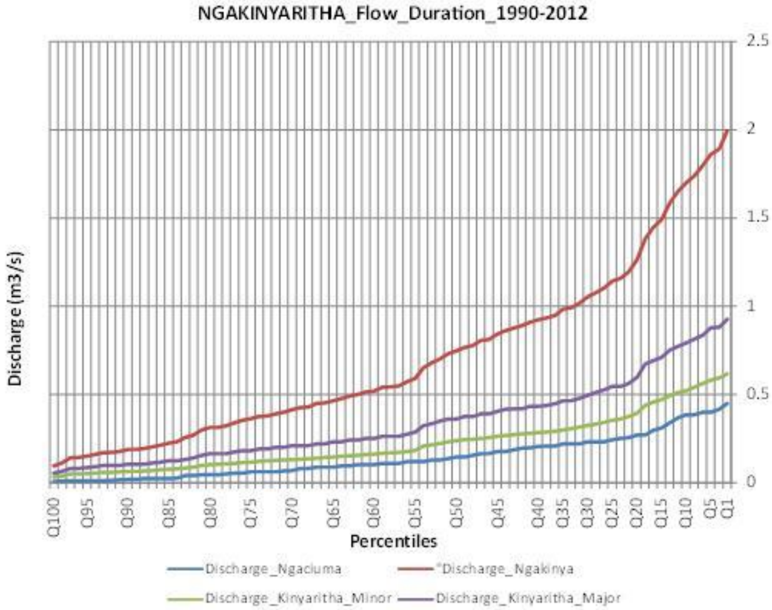

Figure 3. Flow duration for Ngaciuma-Kinyaritha (1992-2012)

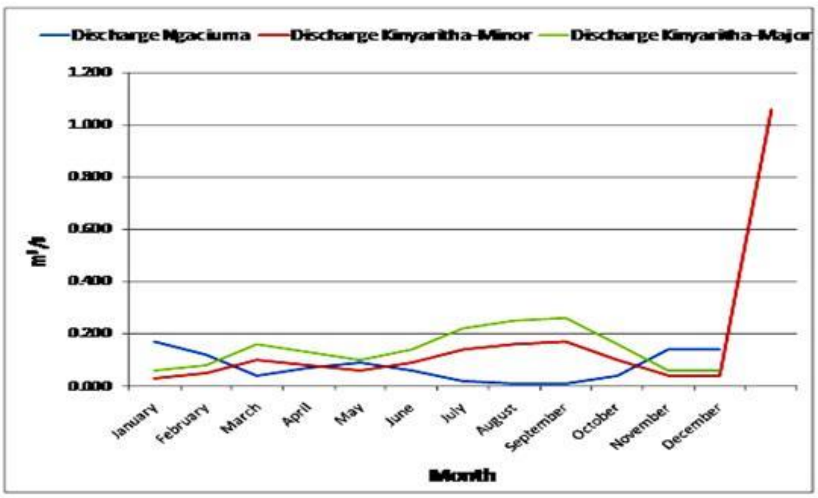

Figure 4. Seasonal behaviour of Ngaciuma-Kinyaritha tributaries

(2) Status of Water Demand (1990-2012)

The total water demand for Ngaciuma-Kinyaritha Catchment in 2012 amounted to 18,025,733.23 m^3It was based on data collected during the hydrological survey conducted in the year 2012. This water demand was dominated by farming water demand, which amounted to 73.1%, followed by 17.5% abstracted by households for domestic use.Water demand for livestock accounted for 9.1%, and lastly industrial and institutional water demands accounting for 0.2% and 0.1%, respectively. Predictions for the period 1990-2012 were based on these results and the ones by Förch, (2008), with an assumption of annual exponential growth of 5.3% (Table 2).

Table 2. Predictions of water demand in Ngaciuma-Kinyaritha (t =0, 2012)

Water Demand Source	*Variables*	*Unstandardized Coefficients*		*Standardized Coefficients*		
		B	Std. Error	Beta	t	Sig.
Farming (Exponential Fit; R^2= 0.968; n=23)	Case Sequence	0.053	0.002	0.984	24.078	0.000
	Constant	13,168,006.1	366,907.305		35.889	0.000
Household (Exponential Fit; R^2= 0.968; n=23)	Case Sequence	0.053	0.002	0.984	24.078	0.000
	Constant	3,155,147.012	87,913.575		35.889	0.000
Livestock (Exponential Fit; R^2= 0.968; n=23)	Case Sequence	0.053	0.002	0.984	24.078	0.000
	Constant	1,641,401.722	45,735.268		35.889	0.000
Industries (Exponential Fit; R^2= 0.968; n=23)	Case Sequence	0.053	0.002	0.984	24.078	0.000
	Constant	37,715.5	1,050.887		35.889	0.000
Institutions (Exponential Fit; R^2= 0.968; n=23)	Case Sequence	0.053	0.002	0.984	24.078	0.000
	Constant	23,462.896	653.759		35.889	0.000

It shall be noted that the Meru Water and Sewerage Society (MEWASS) and other water projects operating under Ngaciuma-Kinyaritha Water Resource Users' Association (Ngakinya WRUA) supplied about 75% of the daily water demand in 2012 estimated to 50,071.481 m^3. The remainder was naturally supplemented directly from rainfall, wells, springs and streams. Besides, Appendix 2 shows that the major instutional water abstractors in the catchment include health centres and clinics, primary and secondary schools, Meru Teachers College, Meru Technical College and the Kenya Methodist University. Moreover, mini bakeries and coffee factories are the main industries operating in the catchment.

Future Status of Water Balance in Ngaciuma-Kinyaritha (2013-2035)

(1) NOR Scenario

Fig. 5 illustrates deepening water deficits in Ngaciuma-Kinyaritha Catchment since 2009 under normal weather conditions (NOR scenario) and in the assumption that an ecological base flow (EBF) was not being enforced. The total water deficit is predicted to be closer to 60 million m^3 by the year 2035 as a result of shrinking water resources (slightly below 1 million m^3), while the total water demand would have attained the 60,995,516.46 m^3.

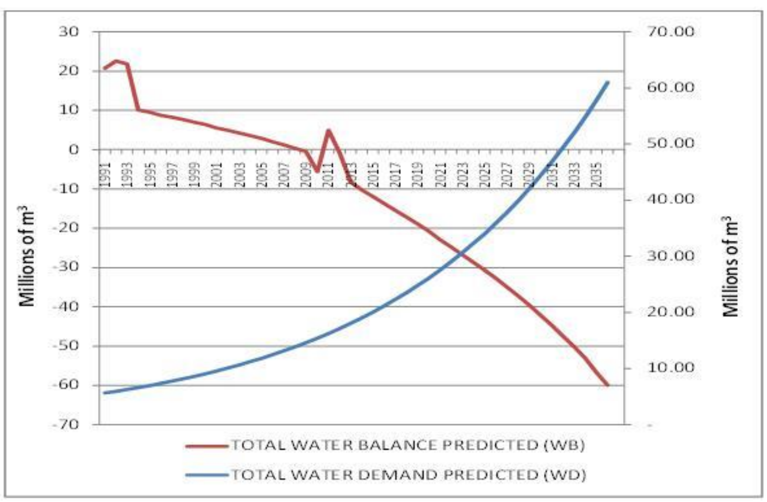

Figure 5. Water deficits in Ngaciuma-Kinyaritha under NOR scenario

Notes: The trendlines obtained from the above curves are given below:

WB = -2,168E+03 t + 2,555E+04 (R^2 = 0.955; t=0 for 2012)

WD = $5E+06e^{0.053\,t}$ (R^2 =0.998; t=0 for 2012)

(2) XSCAR Scenario

The total water balance in Ngaciuma-Kinyaritha Catchment was to be negative starting from 1993, assumption made of water scarcity under extreme dry conditions (XSCAR scenario) per the rainfall turnover of April 2009 (r = 0.4948). Projected water deficit for the year 2012 and 2035 amounted to 26,658,985.91 and 105,995,684.53 m^3, respectively, while water demands would amount to 31,470,267.46 and 106,489,161.48 m^3, respectively (Fig. 6). These deficits would represent about 84.7 and 99.5% unmet water demands in the catchment, agriculture and forestry representing more than 95% of the total demand.

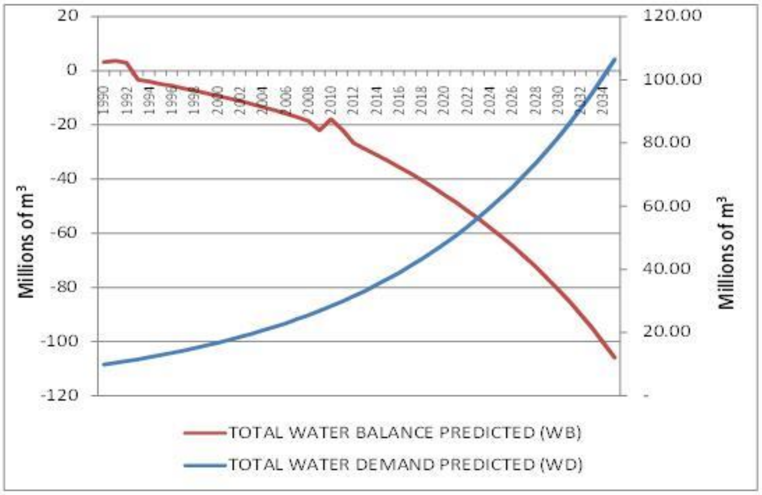

Figure 6. Water deficits in Ngaciuma-Kinyaritha under XSCAR scenario
Notes: The trendlines obtained from the above curves are given below:
WB = -2E+06x + 2E+07 (R^2 = 0.934; t=1 for 2012)
WD = 9E+06e$^{0.053x}$ (R^2 =0.998; t=0 for 2012)

(3) XLOSS Scenario

Based on the rainfall turnover of Dec. 1990 (r = 2.021), a positive water balance was predicted for Ngaciuma-Kinyaritha from 1990 to 2015 hypothesized water loss under extreme flooding weather conditions (XLOSS scenario) (Fig. 7).

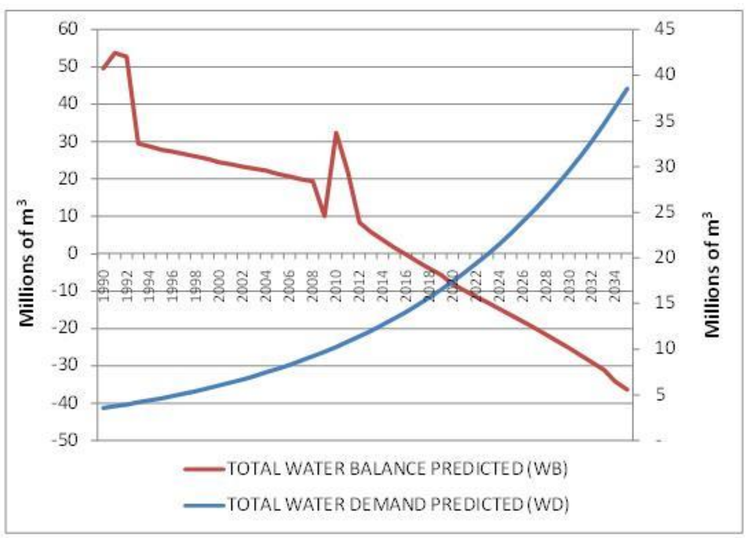

Figure 7. Water balance in Ngaciuma-Kinyaritha under the XLOSS scenario
Notes: The trendlines obtained from the above curves are given below:
WB = -2E+06x + 5E+07 (R^2 = 0.945; t=0 for 2012)
WD 3E+06e$^{0.053x}$ (R^2 =0.998; t=0 for 2012)

Ngaciuma-Kinyaritha Catchment would enjoy a water balance of 8,278,079.11 m^3 representing 72.8% of the total water demand estimated to 11,373,316.49 m^3 in the year 2012. Starting by the year 2016, water deficits of 2.1% of the total water demand are expected as the result of increasing water demand for domestic and instutional use. By the year 2035, Ngaciuma-Kinyaritha Catchment would have recorded unmet demands of 36,469,476.33 m^3 representing 94.8% of the total water demand estimated to 38,485,053.81 m^3.

DISCUSSION

One can easily tell that Ngaciuma-Kinyaritha Catchment might have experienced water insecurity in 2013 if an ecological base flow (EBF) of 30% was enforced by the water resource management authorities under any climatic conditions, except the XLOSS scenario (Flooding). Such an action would be detrimental to local stakeholders but healthy to ecological and biological systems. In the year 2012, a deficit of 8,302,133.23 m^3 was estimated from total water resources of 9,723,600 m^3 and total water demand of 18, 025,733.23 m^3 under normal climatic conditions. Yet, the modeler did not assume that an EBF was being imposed on in-stream water resources. But if 30% of the streamflow were to be reserved for environmental conservation, the status of water security in this catchment would have been more wanting than it is predicted above (Fig. 5).

The enforcement of an EBF would likely prevent local stakeholders to abstract substantial water reserves in the catchment for the sake of environmental sustainability and in-stream water increase. However, community ability to effectively manage water resources and access to water services is compromised as men misuse water and land resources, finances, industries and other firms as well as their own governance (Crow and Sultana, 2002). This water insecurity puts water resources under considerable pressure, hampering the harmonious functioning of various ecological systems and altering the global hydrologic cycle. Consequently, human overuse of water resources, primarily in agriculture, has diffused contamination of freshwater for domestic use. In turn, urban water pollution has affected agricultural lands and the ecological functions of water bodies, soils and groundwater in the water cycle and vice-versa, through filtration, natural decomposition of pollutants and buffer capacity (Gleick, 2003; DeWit and Stankiewicz, 2006).

At the global scale, water insecurity is the fact of global changes, be they climatic, demographic and economic changes, which have serious consequences on the people and the environment (Huggins, 2002; Gleditsch, 2004). Water insecurity in many parts of the world is increasing in terms of water quantity as well as quality. Human appropriation of surface and ground water, changes in land use and land cover, release of pollutants into the environment, and other pressures are also contributing to increased levels of water insecurity (Shivoga, 2007). The resulting degradation of water resources and lack of access to safe water threaten human well being and development, and are intimately linked to poverty in many parts of the world. Aquatic and terrestrial ecosystem structure and functioning also critically depend on availability of sufficient amounts of water and its temporal distribution. Humans being both the causes and casualties of water insecurity, there is need for satisfying solutions to this crisis.

Likewise, there will be both humanitarian and environmental disasters in Ngaciuma-Kinyaritha under hypothesized drought conditions in Ngaciuma-Kinyaritha. There would be no way to reserve 10% of the total streamflow for basic human needs and 20% of streamflow for other biological and ecological systems. The determination observed from some communities to solving various water crises arising from environmental, socio-political and economic changes shall not be ignored. Therefore, contingency plans and measures need to be taken by WRUAs in conjunction with existing CWMSs to avoid such disasters. At the same time, divergent social positions of men and women shall be contextualized to account for their differences in water use, water rights and access to water, which lead to “water insecurity” (Zwarteveen and Meinzen-Dick, 2001). It shall be noted that, although women undertake the large share of domestic work, they receive fewer benefits, most of their work going unpaid (Maharaj, 1999; Suda, 2000). The strategic water development in Ngaciuma-Kinyaritha Catchment shall be a palliative solution to all these issues so as to halve the increasing gap between supply and demand of water and land resources (Pendzich, 1994). But more important, it shall be meant to shape regional landscapes in Mount Kenya and revitalize the functioning of ecosystems and the well-being of humans (Emerton and Bos, 2004; Falkernmark and Röckstrom, 2004). This strategic catchment management shall become the backbone of economic growth and prosperity, social welfare for all stakeholders living in Ngaciuma-Kinyaritha Catchment.

CONCLUSIONS AND RECOMMENDATIONS

Förch, (2008) predicted that the total water resource in Ngaciuma-Kinyaritha would amount to the double of 15,288,105 m^3 in the year 2008, while the total water demand was estimated to 13,854,679 m^3, thus leading to a water surplus of about 16,721,531 m^3. This study predicted a water surplus of 19,312,300.39 m^3 for year 2008 under a hypothesized flooding (the XLOSS scenario), which corroborates with the above findings. These results still call for caution on the side of Ngakinya WRUA, if maintenance of the catchment conditions and coordination of water allocation and use therein is to be achieved at the desired water security in the catchment by the year 2035.

Most of the results in this study demonstrate that the status of water security in Ngaciuma-Kinyaritha Catchment is volatile and needs to be urgently addressed. One of the avenues suggested is the taking into consideration of the role of

CWMSs in ensuring social inclusion in water supply, catchment management and water disaster preparedness. Though informal, these self-help groups have ever played a very important role in assuring social consensus and "sustainability" in water resources management. Not only they have partly contributed to the achievement of the targets of the water sector reforms, they have also empowered local communities to take their own destiny at hand, without waiting for governmental interventions. Moreover, under their leadership, community members have become more inclined to understand physical social and economic interactions between their water resources and the principles governing IWM. Hence, WRMA and WRUA can incorporate them in their strategic management to achieve to their full potential the targets of the water sector reforms in Ngaciuma-Kinyaritha Catchment.

REFERENCES

Agwata JF. 2006. Resource potential of the Tana Basin with particular Focus on the Bwathonaro Watershed, Kenya. FWU publications, Vol. 5, 1-15.

Bouwer H. 2003. Integrated Water management for the 21st Century: Problems and Solutions. Food Agriculture and Environment, Vol. 1 (1), 18-127.

Ayling, R and Kelly K. 1997. Dealing with conflict: natural resources and dispute resolution. Commonwealth Forestry Review, 76 (3), 182–185.

Calder IR. 2005. Blue Revolution, Earthscan, London, UK.

Crow B and Sultana F. 2002. Gender, class, and access to water: three cases in a poor and crowed delta. Society and Natural Resources (15), 709–724.

DeWit M and Stankiewicz J. 2006. Changes in Surface Water Supply Across Africa with Predicted Climate Change. Science express (2), March 2006.

Emerton L and Bos E. 2004. Value – Counting Ecosystems as Water Infrastructure. IUCN, Gland, Switzerland.

Falkenmark M and Rockström J. 2004. Balancing Water for Humans and Nature. Earthscan, London, UK.

Förch G, Winnegge R and Thiemann S. 2007. DAAD Alumni Summer School: Participatory Monitoring of Sub-Catchment Management Planning – Bwathonaro Watershed, Kenya, Final Report, August 2007. Universitat Siegen and Kenyatta University, Meru, Kenya.

Förch G, Winnegge R and Thiemann S. 2008. DAAD Alumni Summer School : Water Demand in Participatory Watershed Management – Ngaciuma-Kinyaritha Watershed, Kenya, Final Report, November 2008. Universitat Siegen and Kenyatta University, Meru, Kenya.

Gleditsch NP, Owen T, Furlong K and Lacina B. 2004. Conflicts over Shared Rivers: Resource Wars or Fuzzy Boundaries? Paper presented to the 4th Annual Convention of the International Water Studies Association, Montreal, Canada, March 2004.

Gleick P. 2003. Global Freshwater Resources: Soft-Path Solutions for the 21st Century. Science, Vol. 302 (5650), 1524-1528.

GWP. 2000. Integrated Water Resources Management. Global Water Partnership (GWP), TAC background paper No 4

Hirsch P, Phanvilay K and Tubtim K. 1999. Nam Ngum, Lao PDR: Community-based natural resource management and conflicts over watershed resources. In: Buckles, D. (Ed). Cultivating Peace: Conflict and Collaboration in Natural Resource Management. International Development Research Centre, World Bank Institute, Washington DC, USA.

Huggins C. 2002. Water Policy and Law in a Water-Scarce Country, in Murray-Rust and Blank (eds)(2002), The Changing Face of Irrigation in Kenya. International Water Management Institute, Colombo, Sri Lanka.

Jaetzold R, Schmidt H, Hortnetz B and Shisanya C. 2007. Farm Management handbooks of Kenya, vol. II: Natural conditions and farm management information, "Part C East Kenya, Subpart C1 Eastern Province". Ministry of Agriculture and GTZ, Nairobi, Kenya, pp. 1-571.

Katui-Katua M. 2004. Drawers of Water II: Kenya Country Report. International Institute for Environment and Development, London, UK.

KNBS. 2007. Kenya Vision 2030. Available at: http:// www.investmentkenya.com/Documents/Publications/vision_2030_BROCHURE_July_2007. pdf.

Lankford BA, van Koppen B, Franks T and Mahoo H. 2004. Entrenched views or insufficient science? Contested causes and solutions of water allocation; insights from the Great Ruaha River Basin, Tanzania. Agricultural Water Management, 69(2), 135-153

Lelo FK, Chiuri W and Jenkins MW. 2005. Managing the River Njoro Watershed, Kenya: Conflicting laws, policies, and community priorities. In: Republic of South Africa (Eds), African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa, Johannesburg, South Africa.

Luwesi CN, Shisanya CA and Obando JA. 2012. Warming and Greening - The Dilemma Facing Green Water Economy under Changing Micro-Climatic Conditions in Muooni Catchment (Machakos, Kenya). Saarbrüken, Lambert Academic Publishing AG & CO.KG.

Maharaj N, Kusum A, Garcia Vargas M and Richardson G. 1999. Mainstreaming Gender in Water Resources Management: Why and How. Background Paper for the World Water Vision 1999. World Water Council, Paris, France.

Malzbender D, Goldin J, Turton A and Earle A. 2005. Traditional Water Governance and South Africa's "National Water Act" – Tension or Cooperation? In: Republic of South Africa (Eds), African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa, Johannesburg, South Africa.

Mogaka H, Gichere S, Davis R and Hirji R. 2006. Climate Variability and Water Resources Degradation in Kenya. Improving Water Resources Development and Management. The World Bank Working Paper No. 69. The International Bank for Reconstruction and Development, The World Bank, Washington, DC., USA.

Mumma A, Lane M, Kairu E, Tuinhof A and Hirji R. 2011. Kenya Groundwater Governance Case Study. Water Papers, June 2011. Water and Sanitation Program (WSP), The World Bank, Washington, D.C. Available online at URL: http://www.worldbank.org/water. Accessed on 01 October 2009.

Ngigi A and Macharia D. 2007. Kenya Water Sector Overview. Nairobi, IT Power East Africa.

Nishimoto S. 2003. Mainstreaming Gender in Water Management: A practical journey to Sustainability. A Resource Guide. Environmentally Sustainable Development Group. Bureau for Development Policy. UNDP, New York, USA.

Njonjo A and Lane J. 2002. Rural Piped Water Supplies in Ethiopia, Malawi and Kenya: Community management and Sustainability. Water and Sanitation Program, Field Note 13; http://www.wsp.org/filez/pubs/328200711859_RuralPipedWater.pdf. Accessed on 01 October 2009.

Pendzich C, Thomas G and Wohlgenant T. 1994. The role of alternative conflict management in community forestry. Food and Agriculture Organization (FAO), Rome, Italy.

Ramírez R. 1999. Stakeholder analysis and conflict management In: Buckles, D. (Ed). Cultivating Peace: Conflict and Collaboration in Natural Resource Management. International Development Research Centre (IDRC), World Bank Institute (WBI), Washington DC., USA.

Republic of Kenya. 2002. The Water Bill, 2002. In Kenya Gazette Supplement, Bills 2002. Government Printer, Nairobi, Kenya, pp 287–413.

Shaftoe D. 1993. Responding to changing times: environmental mediation in Canada. Interaction for Conflict Resolution. Waterloo, ON, Canada.

Shakya NM. 2001. Impact of forest clearing on hydrology: Mathematical modelling of Khageri River. In Subramanian V. and Ramanathan A. (eds), Ecohydrology, Capital Publishing Company, New Delhi, India, pp. 355-368.

Shisanya CA and Kwena ZA. 2005. An Analysis of Accessibility to Rural Domestic Water Supply: A Case Study of Kakamega District, Kenya. In: Libor Jansky, Martin J. Haigh and Haushila Prasad (eds.), Sustainable Management of headwater resources-Research from Africa and India: 178-202.

Shivoga WA, Muchiri M, Kibichi S, Odanga J, Miller SN, Baldyga TJ, Enanga EM and Gichaba MC. 2007. Influences of Land Use/cover on Water Quality in the Upper and Middle Reaches of River Njoro, Kenya. Lakes & Reservoirs: Research and Management 12: 97–105.

Suda C. 2000. Gender, culture and environmental conservation in Western Kenya: contextualizing community participation and the choice of techniques. Nordic Journal of African Studies, Vol. 9 (1): 31–48.

Swallow B. 2005. Potential for poverty reduction strategies to address community priorities: case study of Kenya. World Development, Vol. 33 (2): 301–321.

Van Aalst MK. 2006. The Impacts of Climate Change on Risk of Natural Disasters. Disasters 30: 5-18.

Van Koppen B. 2007. Community-Based Water Law and Water Resource Management Reform in Developing Countries. CABI, London, UK.

Were E, Swallow B and Roy J. 2006. Water, Women, and Local Social Organization in the Western Kenya Highlands. CAPRi Working Paper 51. International Food Policy Research Institute (IFPRI), Washington, DC., USA.

WHO and UNICEF. 2004. Coverage Estimates, Improved Drinking Water, Kenya. World Health Organization/United Nations Children's Fund, Joint Monitoring Program for Water Supply and Sanitation, Geneva, Switzerland. Accessed on 01 October 2009.

World Bank. 2009. BasinIT: An Interactive Tool for Basin Water Planning. The World Bank Institute (WBI) website: http://worldbank.mrooms.net/course/view.php?id=346. Accessed on 03. 04. 2008.

WRI. 2003. Water Resources and Freshwater Ecosystems—Kenya. Earth Trends Country Profiles. World Resources Institute (WRI) website: http://earthtrends.wri.org/pdf_library/country_profiles/wat_cou_404.pdf. Accessed on 01 October 2009.

Zwarteveen M and Meinzen-Dick R. 2001. Gender and property rights in the commons: examples of water rights in South Asia. Agriculture and Human Values, Vol. 18 (1): 11–25.