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Characterization of Water Source Types and Uses in Kirisia Forest Watershed, Samburu County, Kenya

John Warui Kiringe[1], Francis Mwaura[2] & Fiesta Warinwa[3]

[1] Habitat Planners, P.O. Box 10982-00100 Nairobi, Kenya

[2] Department of Geography & Environmental Studies, University of Nairobi, Box 30197-00100, Nairobi, Kenya

[3] African Wildlife Foundation (AWF), P.O. Box 310-00502, Nairobi, Kenya

Correspondence: John Warui Kiringe, Habitat Planners, P.O. Box 10982-00100 Nairobi, Kenya. Tel:254-722-896-632. E-mail: jwkiringe@gmail.com

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Abstract

Kenya's dry-land water catchments are valued for their water provision services but their conservation is given little attention. This study was carried out between October and December 2015 and documented water source types and uses by humans and livestock in Kirisia Forest watershed. Different water source types exist in the watershed including earth dams, water pans, shallow wells, boreholes, springs and streams. The estimated population of livestock and locals using these sources was 180,645 and 147, 060 respectively. Earth dams and water pans provided water to the highest population of community members estimated at 11,564 people followed by boreholes at 9,886 people while streams, springs and shallow wells were used by the least number of people. They also provided water to the highest number of livestock estimated at an average of 15,422 animals. The highest amount of water was abstracted from boreholes at nearly 197,720Litres/day (197.72m^3/day) followed by earth dams and water pans at 91,960Litres/day (91.96m^3/day), and the least was from shallow wells, springs and streams at about 38,000Litres/day (38m^3/day). Daily water abstraction from all the water source types by humans and livestock was nearly 366,540Litres/day or 366.54m^3/day. Twenty three sub-locations rely on water from the watershed and based on the 2009 population census, their projected water demand was approximately 182,238,520Litres/day (182,238.52 m^3/day). Water demand by livestock was estimated at 12,172,600Litres/day (12,172.60m^3/day) based on the 2013 population data. Overall water demand by humans and livestock in all the sub-locations was estimated at 194,411,120Litres/day (194,411.12 m^3/day); and these findings demonstrate the critical role played by the watershed in sustaining locals livelihoods and pastoralism.

Keywords: Kirisia Forest watershed, local livelihoods, Samburu County, water demand, water source types

1. Introduction

Societies the world over rely entirely on the earth's ecosystems and the different services they provide including food production, water provisioning, climate regulation and amelioration, disease management and spiritual fulfillment (MEA, 2005). Thus, Ecosystem Services (ES) can be viewed as benefits that humans get from ecosystems either directly or indirectly (Daily, 1997; de Groot, Matthew & Roelof, 2002). Nonetheless, in the last century, humans have changed ecosystems primarily to meet a growing demand for fuel, fresh water, food, fiber and timber. While exploitation of ecosystems and their transformations have substantially improved livelihoods and contributed to rapid socio-economic development, its ramifications on environmental health has created a lot of concern (MEA, 2005). In recognition of the value of Ecosystem Services to humans, a lot of attention has focused on preserving the earth's ecosystems and natural resources in general. Nonetheless the importance of services provided by ecosystems for human welfare is not new, and dates back to the time of Plato, and economic conceptualization of ecosystem values (Costanza et al., 1997).

Water is central to survival of humans and environmental integrity but it also supports food and energy production, recreation, manufacturing and industrial processing. It's therefore one of the Ecosystem Services that currently receives a lot of attention because of its role in sustaining human life and the environment (Gleick, 2003; MEA, 2005). Most hydrological services occur in highlands of forest watersheds, which work as natural systems that; collects, manufactures, and distributes water and provides hydrological services to lowlands (GWP, 2000; MEA, 2005; Perez-Verdin, Navar-Chaidez, Kim, & Silva-Flores, 2012). Thus, key aspects of the water cycle, mainly; water infiltration, water surface run-off, evaporation is partly dependent on the state of forest cover. If forest cover decreases substantially, it ultimately lowers the water quantity and quality that is available to downstream users (Wu, Kim & Hurteau, 2011). Since watershed services benefit nature and people, they are the most appropriate units for water management because they represent landscapes that harness rainfall and channel it to rivers, streams, springs, wetlands and aquifers (MEA, 2005).

In Kenya, water is the foundation of livelihoods in rural and urban areas but most parts of the country are faced by exceptionally high water demand amidst a decline in its availability (Mogaka, Gichere, Davis, & Hirji, 2006). This situation is worse in dry areas which make up nearly 80% of country's land mass, and where water resources are naturally scarce (Mogaka et al., 2006). Accordingly, the United Nations (UN) has classified Kenya as a chronically water-scarce country (RoK, 1991), and freshwater availability is very limited with an annual renewable supply of about 647m^3 per capita, which is way below the 1,000 m^3 per capita set as the benchmark for water scarcity. The country's economy is predominantly rural-based and mainly dependent on natural resources (Mogaka et al., 2006; GoK, 2007); and water is a key backbone for sectors such as energy, agriculture, fisheries, livestock and tourism (RoK. 1991; Mogaka et al., 2006; GoK, 2007). In this regard, the National Water Policy Sessional Paper No. 1 of 1999 on Water Resources Management and Development, and the National Development Plans laid great emphasis on the importance of water in achievement of the country's development goals and Sustainable Development Goals (SDGs) (GoK, 2007). According to GoK (2007), Kenya's vision of poverty reduction and promotion of strong and sustainable socio-economic development is partly pegged to provision of water resources in all parts of the country. Hence, degradation, general mismanagement and wastage of water present a big setback in the country's socio-economic development agenda. Based on scanty data, Mogaka et al. (2006) estimated that degradation of water resources costs the country nearly 0.5% of the Gross Domestic Product (GDP) or an equivalent of Ksh. 3.3million each year.

The World Bank proposes that; pollution, lack of climate variability preparations, rampant degradation and mismanagement of water resources have increasingly slowed down economic growth and perpetuated poverty not only in Kenya but across the entire African continent (Grey & Sadoff, 2002). Over the years most parts of Kenya have been characterized by wide-spread misuse and poor conservation of water resources, water theft and corruption, and its allocation is mostly made using inadequate hydrological data and information (RoK, 1991; Mogaka et al., 2006; Kiringe, Okello, Tome, & Seno, 2009). The effects of this situation are felt more in water-stressed areas particularly dry-lands or the country's rangelands. Groundwater resources have not been spared either and these have been over-exploited way beyond the natural capacity of the hydrological system to replenish them. Decline in water quality has also been rampant through agricultural, urban and industrial wastes and massive deposits of sediments emanating from degraded landscapes.

Past studies have shown Kirisia Forest is increasingly getting deforested and degraded due to; frequent forest fires, wood fuel harvesting, illegal human settlements and logging of high quality trees, livestock grazing and fodder harvesting (Watai & Gachathi, 2003; Lambrechts, Woodley & Gachanja, 2005; Anne, 2009; KFS, 2012; Nyaligu, 2013). This is a big threat to the ecological integrity and forest cover of the watershed, and its natural ability to replenish water resources and provision of other environmental goods and services. Forests play an important role in water and soil conservation, mainly; regulation of water flow and control of watershed erosion and floods (LVBC, 2011). But when their vegetation cover is interfered with substantially, these functions are usually reduced leading to decline in quantity and quality of water flowing downstream from the watershed (Honeck & Smith 1992; KWS, 2002; Akotsi, Gachanja & Ndirangu, 2006; Olang & Kundu, 2011; Gichuhi, 2013). In this regard, Kirisia Forest watershed will only continue to provide valuable goods and services to locals on a sustainable basis if it's secured and the threats facing it are effectively mitigated. Given its role in sustaining the socio-economic well-being of local communities, it's imperative that it's conserved and managed as a local and national livelihood and economic treasure. Failure to do so will trigger a cascade of negative impacts such as prevalence of water conflicts and decline of; local livelihoods, pastoralism and wildlife based tourism. In the long-term it will impede and slow down the socio-economic aspirations of local communities.

Availability of adequate water is a key bottleneck to sustainable socio-economic development, improved livelihoods and poverty reduction in Samburu County, and other dry regions of Kenya (RoK, 1991, 2010, 2013; Mogaka et al., 2006). So, high altitude forests in the country like Kirisia are critical water catchments and supply water which supports local livelihoods, pastoralism and wildlife conservation (RoK, 1991). Nyaligu (2013) carried out an inventory on the status of water in Kirisia Forest and his findings revealed a worrisome situation on the ability of the forest to continue supplying adequate water to meet the needs of different users. Thus, our study focused on the following objectives; i) delineation of the spatial coverage of Kirisia Forest watershed and its drainage system, ii) document water source types, and, iii) assess water use and demand levels by humans and livestock.

2. Area Description

Kirisia Forest also locally known as Leroghi is one of the forested high altitude landscapes in Samburu County in the northern part of Kenya (Figure 1); and lies at an altitude of 2,000 to 2,200m ASL (Watai & Gachathi, 2003; Hitimana et al.2005). It's one of the oldest state protected areas in the country and was gazetted by the British administration in 1933 (Watai & Gichohi, 2003; Ngaligu, 2013). At time of gazettement, the forest covered nearly 92,000ha but thereafter its acreage was systematically reduced, and currently covers less than 780Km^2 (Watai & Gachathi, 2003; Hitimana et al., 2005; Anne, 2009). The mean annual rainfall in the forest and its environs ranges between 600 – 750mm, and is received thrice a year with January and February being the driest (Watai & Gachathi, 2003; Anne, 2009; Nyaligu 2013). According to Kiringe, Mwaura and Kimeu (2015b) the northern zone of the forest like Porro area typically receive a slightly higher mean annual rainfall of about 575mm compared to the central region around Mararal town which receives a mean annual rainfall of 563mm while the southern zone in Baawa area has the lowest at 552mm.

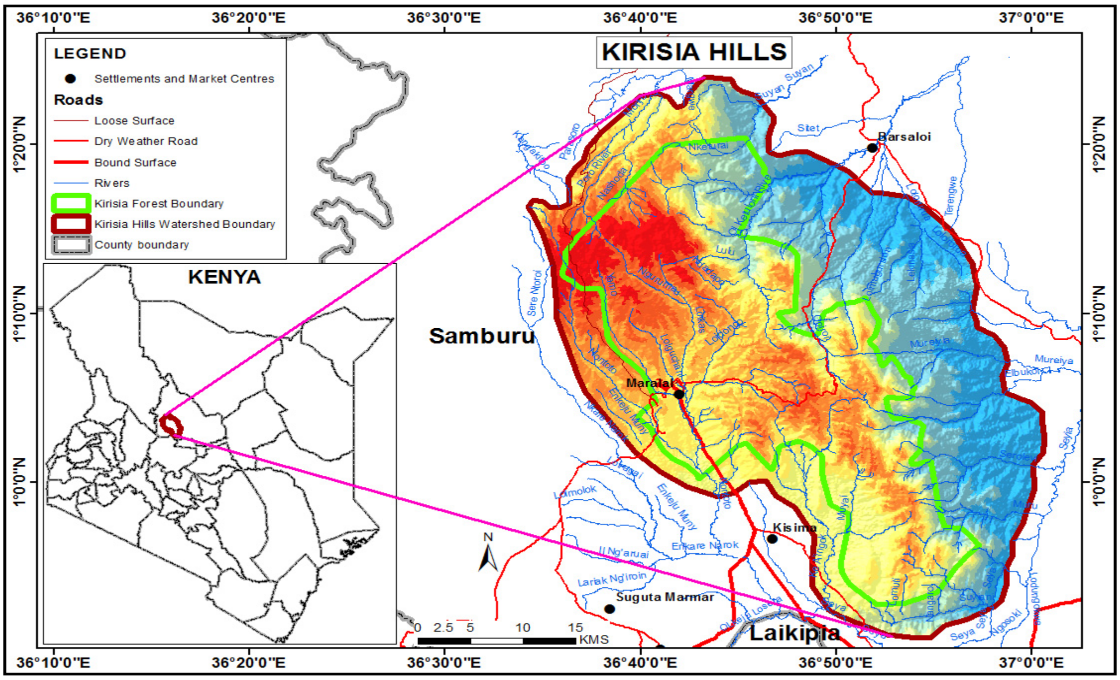

Figure 1. Location of Kirisia Forest and its watershed in Samburu County

The region where the forest is situated is classified as a semi-arid environment, and lies in agro-ecological zone IV-VI (Pratt & Gwynne, 1977). But due to its tri-modal rainfall and high altitude, the forest acts as an important dry-land water tower (Nyaligu, 2013), and is a critical water source for the local communities especially the pastoral Samburu who are dominant inhabitants in the region (Watai & Gachathi, 2003; Anne, 2009; Nyagilu, 2013). Pastoralism is the main land use although mixed crop-livestock farming is done in wetter areas like Porro where maize, wheat and other crops are grown (Hitimana et al., 2005; Anne, 2009). Kirisia Forest is the foundation of local livelihoods and provides various goods and services including dry season grazing grounds and watering sites, livestock fodder, construction materials, herbal medicine, honey and wood-fuel (Watai & Gachathi, 2003; Anne, 2009; KFS, 2012). Communities in the immediate environs of the forest live in thirteen group ranches which were created under the Kenya Livestock Development Project of 1968-1980 (Anne, 2009; Hitimana et al., 2011). But the Dorobo people who are mainly hunter-gatherers live within the forest which forms the backbone of their livelihoods.

According to Beentje (1990) Kirisia Forest has diverse vegetation communities, and four woody plant species tend to dominate the forest top canopy; *Olea europaea* spp *africana* (up to 34 %), *Juniperus procera* (up to 25%), *Podocarpus falcatus* (up to 26 %) and *Croton megalocarpus* (15 %). Those species dominating the middle canopy are; *P. falcatus* (12-45 %), *Olea. europaea* spp a*fricana* (21-28%), *Juniperus procera* (20 %), *Teclea simplicifolia* (13-15 %) and *Croton. megalocarpus* (12 %). The disturbed and rocky areas of the forest are characterized by small sized trees and shrubs such as; *Euclea divinorum*, *Carissa edulis*, *Rhus natalensis* and *Croton dichogamus*. Apart from woody flora biodiversity, the forest also supports a variety of large mammalian wildlife species including; the African elephant (*Loxondonta africana*), olive baboon (*Papio anubis*), giant forest hog (*Hylochoerus meinertzhageni*), cape buffalo (*Syncerus cafer*), common zebra *(Equus burchelli*), bush-buck (*Tragelaphus scriptus*), eland (*Taurotagus oryx*), common warthog (*Phacochoerus aethiops*), Maasai giraffe *Giraffa camoleopardis tippelskirchi)*, lion (*Panthera leo*) and spotted hyena *(Crocuta crocuta)* (Watai & Gachathi, 2003; Hitimana et al., 2005; Anne, 2009).

3. Methods

3.1 Watershed and Drainage Network Delineation

Kirisia Forest watershed layout was demarcated using 30m ASTER Digital Elevation Model (DEM) satellite data based on the drainage network. ASTER satellite data was presented on ArcGIS software window and overlapped on the watershed drainage layer. The layout of the watershed boundary was then obtained by digitizing a polygon using DEM and surface water flow direction on the landscape; and the polygon then depicted the forest watershed layout in which the study was then focused. The spatial extent of the drainage network within the Northern, Southern, Eastern and Western zones of the watershed was determined using satellite imageries. This data was used to establish the total length (in kilometers) and drainage density of rivers and streams in each zone.

3.2 Documentation of Water Source Type and Usage

An inventory of water source types was done using drive-through transects traversing different zones of the watershed, and local Samburu guides acted as translators. This was supplemented by walking through non-motorable landscapes. When a water source was encountered the following information was noted; i) type of surface water source (e.g. spring, stream, water pan or earth dam) and type of ground water source (borehole and shallow well), ii) geographic location (GPS coordinates) using a hand held Garmin GPS unit), iii) ownership, and, iv) state of the water source i.e. whether it was dry or active and functional. The GPS coordinates were geo-referenced on a topographic map of the watershed using GIS software to create a water source type map. Reports and relevant water documents for the Samburu County where Kirisia Forest is situated were sourced from; Samburu County water offices at Maralal town, African Wildlife Foundation (AWF) Nairobi office and the Water Resources Management Authority (WRMA) office at Rumuruti town. Some of the key information obtained from these reports included the water source types found in the Kirisia Forest watershed and the rest of the county.

Water use at various source types was assessed by interviewing community members with the help of local Samburu translators. Some of the key information gathered from the respondents included; i) number of households, community members and livestock using a given water source type, ii) water uses, and, iii) amount of water used by livestock and abstracted daily (in jerricans) by each household. This information was supplemented with secondary water use data based on reports and records from the Water Resources Management Authority (WRMA) office at Rumuruti Township, AWF office in Nairobi, Samburu County water and works department in Mararal and Samburu Water and Sanitation Company (SAWASCO) office. The key information obtained included; i) typology of water uses, ii) water beneficiaries and their numbers, and, iii) water abstraction (use) levels.

Understanding water demand is important in planning its development and supply. In this regard, we projected human and livestock populations and their associated water demand levels in Samburu Central sub-county which depends on water from Kirisia Forest watershed. Given the dry nature of the region and scarcity of large quantities of water, irrigated agriculture is not possible, and livestock and households (rural and urban populations) are the main water users. In Kenya, human population census is normally done every ten years. Therefore, the projected human population growth in the sub-county for the year 2020 and 2030 was based on the 2009 national population census records (KNBS, 2009). This was done using the equation below and the annual population growth rate for Samburu County which is estimated at 2.10% (KNBS, 2009).

$$P_2=P_1(r/100+1)^t$$

Where:-

- P_1=Population at start of a census period
- P_2=Population at end of the census period in consideration
- t=Time (Number of years of census period in consideration)
- r=Percent annual population growth rate

Estimates of water demand levels in the sub-county by humans for the year 2009 was based on secondary data (KNBS, 2009) while that of 2020 and 2030 were projected based on Samburu County 2009 national households census data. Livestock water demand was based on Samburu Central sub-county 2013 livestock data (RoK, 2013) but it was not possible to account for water use and associated demand level by different species of wildlife found in the watershed.

4. Results

4.1 Watershed and Drainage Network

The drainage system in Kirisia Forest watershed comprises of a variety of seasonal and permanent rivers and springs but due to the state of the environment, they tend to be more seasonal most of the year. Some of the rivers include; Baawa, Baringo, Saanata, Lalmargwet, Nchangalo, Longek, Yaamo, Nashuda, Rapa and Mwata though they are relatively small in size and their permanency and water discharge vary on a seasonal basis. Laggas are also common in the watershed but are usually seasonal in their water provision mainly during the wet season. At the time of this study only three of the many valleys in the watershed had some little water flowing through at; Nachuda stream to the north of Porro, Nangaro springs and Ngonyeki springs in the Baawa area. The drainage network density varied among different zones of the watershed (Figure 2) ranging from 0.461Km to 0.518Km per Km (Table 1).The Northern and Eastern zones had the longest and most dense drainage network followed by the Western and Sothern zones in that order (Table 1 & Figure 2).

Table 1. Drainage network length and density in watershed zones of Kirisia Forest

Watershed zone		Approximate area of watershed zone (Km^2)	Total length of laagas (Km)	Drainage density (length of streams in Km per Km^2)
1	Northern zone	1,096	568	0.518
2	Southern zone	666	307	0.461
3	Eastern zone	1,000	503	0.502
4	Western zone	762	372	0.488

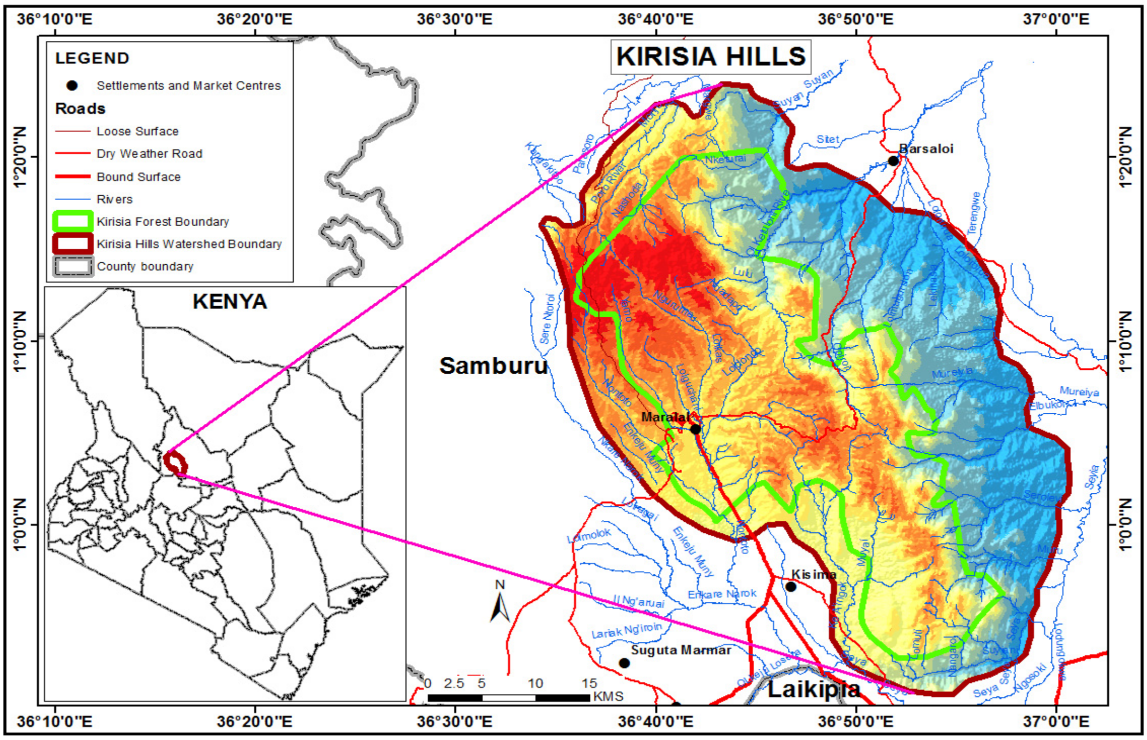

Figure 2. Spatial layout of the Kirisia Forest watershed drainage network

4.2 Water Source Types and Usage

Samburu County is characterized by a dry environment but its climate varies spatially based on variation in landscape altitude. The dry nature and low rainfall characteristics of the county implies that surface water resources are scarce in space and time with ground water in form of boreholes being the most reliable water sources. In this regard, numerous boreholes have been drilled during the colonial days and after independence in an attempt to ensure households have access to reliable water supply. Approximately 644 water sources types exist in Samburu County and are broadly grouped into seven categories (Table 2), and most of them are concentrated in Kirisia Forest watershed and its environs (Figure 3). However, not all of these water sources are operational, and this presents a challenge in regards to ensuring that locals and their livestock have access to water throughout the year. Earth dam are the most common (213) followed by shallows (141), water pans(112) and boreholes(104) in that order (Table 2) with permanents surface water sources in form of streams and rivers being the least common.

Table 2. Typology of water source types in Samburu County

Type of water source		Estimated total number of water source type
1	Permanent rivers & streams	2
2	Protected springs	35
3	Unprotected springs	37
4	Earth dams	213
5	Water pans	112
6	Boreholes	104
7	Shallow wells	141
Estimated total number of all water source types		644

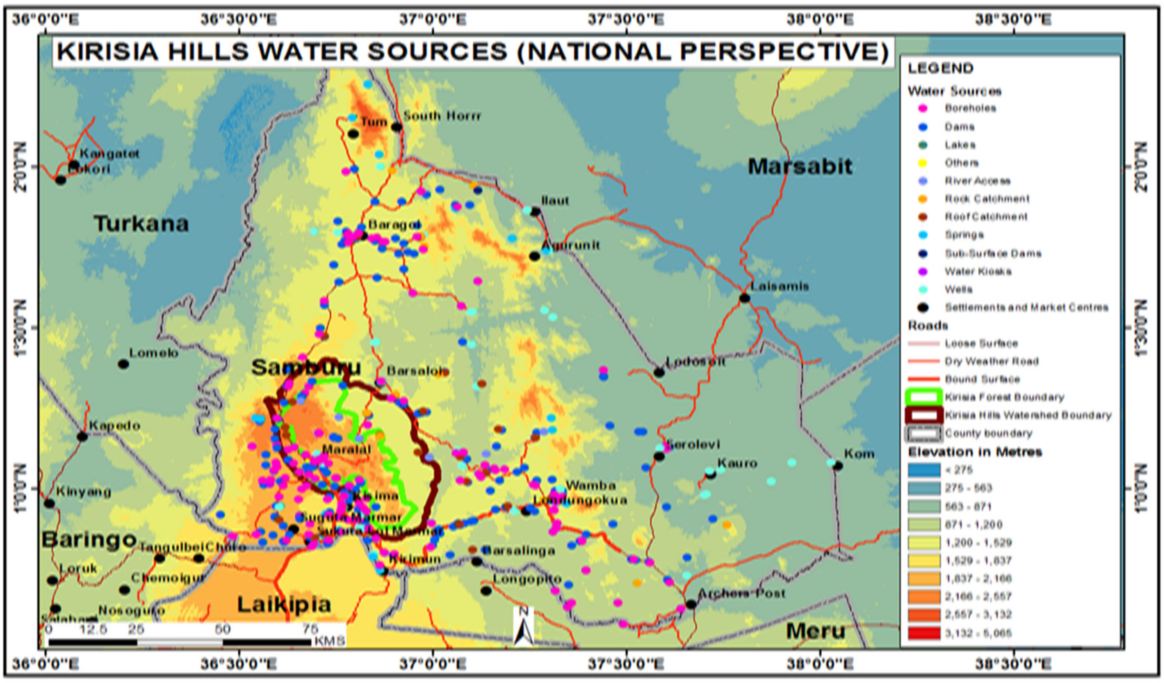

Figure 3. Spatial distribution of water source types in Samburu County (Source: Samburu CIDP 2013-2017)

Our study established that surface and ground water source types existed in Kirisia Forest watershed comprising of; springs, streams, earth dams, water pans, boreholes and shallow wells (Table 3). Some of the key springs included; Ngonyeki, Nang'aro, Soit-Ngablo and Lechoro-Lenanguya while streams were; Naschuda, Naadapo-Elkileku, Lonyunyi and Lorok. Most of these water sources were found in the Northern, North-western and Southern zones of the watershed but no streams and springs were found in the Central zone. Earth dams and water pans were also found in the watershed, and the former were mainly confined in the Southern and Central sectors (Table 3). Only two dry water pans were encountered; Ngabai and Ndikir-Elgwesi Elgwesi, with dams being the most prevalent, and included; Ntontol dam, Su-en dam, Prison dam, Nontotol dam and Suen-Lkidoroto dam. Dams provided water for domestic uses and watering livestock and wildlife. Boreholes and shallow wells were the main ground water sources and were mostly confined to the Northern and Southern zones (Table 3). The key boreholes were; Ngorika, Baawa, Leirr, Lchoro and Partuk 1 owned by SAWASCO and supplied water to Maralal town. Lonkutukie, Ntonlol, Lorok (1, 2 & 3) and Ngablo were some of the shallow wells found in the watershed. The wells and boreholes were critical water sources for households, livestock and wildlife particularly during the dry season when water resources were not readily available in springs, streams, earth dams and water pans.

Table 3. Inventory of water source types found in Kirisia Forest watershed

	Water source types **SPRINGS**	Location in the watershed	GPS Coordinates
1	Ngonyeki	Northern watershed zone	N01.17356^0;E036.70635^0
2	Nang'aro	Southern watershed zone	N 01.02376^0; E 036.81657^0
3	Soit Ngablo	Southern watershed zone	N 01.00474^0; E 036.85241^0
4	Lechoro Lenanguya	Southern watershed zone	N 01.06251^0; E 036.73471^0
#	**STREAMS**		
1	Nashunda	Northern western zone	N 01.27412^0; E 036.65909^0
2	Naadapo Elkileku	Northern western zone	N 01.25484^0; E 036.62896^0
3	Lonyonyi	Northern western zone	N 01.12215^0; E 036.62797^0
4	Lorok	Central watershed zone	N 01. 16813^0, E 036.77607^0
5	Kirisia	Central watershed zone	N 01.08643^0; E 036.71154^0
#	**EARTH DAMS**		
1	Ntontol	Northern watershed zone	N01.28597^0;E036.66153^0
2	Su-en	Central watershed zone	N01.16161^0;E036.74428^0
3	Suen-Lkidoroto	Central watershed zone	N01.15981^0;E036.74540^0
4	Nontotol	Central watershed zone	N01.05713^0;E036.67558^0
5	Loikurukul	Central watershed zone	N01.05293^0;E036.67929^0
6	Baawa	Southern watershed zone	N01.01952^0;E036.81092^0
7	Prison	Southern watershed zone	N01.06392^0;E036.71875^0
8	Morijoi	Southern watershed zone	N01.05020^0;E036.72626^0
#	**WATER PANS**		
1	Ngabai	Northern watershed zone	N 01.23212^0;E 036.65409^0
2	Ndikir Elgwesi	Central watershed zone	N01.15660^0;E036.75555^0
#	**BOREHOLES**		
1	Ngorika	Northern watershed zone	N01.27412^0;E036.65909^0
2	Partuk 1	Central watershed zone	N01.12249^0;E036.62801^0
3	Partuk 2	Central watershed zone	N01.12212^0;E036.62801^0
4	Baawa	Southern watershed zone	N01.02780^0;E036.81181^0
5	Leirr	Southern watershed zone	N01.01065^0;E036.78466^0
6	Lchoro	Southern watershed zone	N01.03459^0;E036.74981^0
#	**SHALLOW WELLS**		
1	Lonkutukie	Northern watershed zone	N01.34551^0;E036.71298^0
2	Ntonlol	Northern watershed zone	N01.28639^0;E036.66094^0
3	Lorok (1, 2 & 3)	Central watershed zone	N01.13754^0;E036.70920^0
4	Loikas	Central watershed zone	N01.13754^0;E036.70920^0
5	Ngablo	Southern watershed zone	N01.00109^0;E036.85105^0
6	Naingolie	Southern watershed zone	N 01.05102^0;036.74687^0
7	Naingolie	Southern watershed zone	N01.04232^0;E036.74277^0

Table 4 summarizes the findings of the estimated number of community members and livestock using the surveyed water source types as well as the approximate amount of water used per day. The approximate total number of livestock and locals using the sources was about 180,645 and 147, 060 respectively. Earth dams and water pans provided water to the highest population of community members estimated at an average of 11,564 people followed by boreholes at 9,886 members (Table 4). Shallow wells, springs and streams were used by the least number of people. In regards to usage by livestock, earth dams and water pans served the highest population of livestock estimated at an average of 15,422 and the other water source types provided water for an almost equal number of livestock at about 7,000 (Table 4). The highest amount of water was abstracted from boreholes at nearly 197,720Litres/day (197.72m^3/day) followed by earth dams and water pans at 91,960Litres/day (91.96m^3/day), and the least was from shallow wells, springs and streams at about 38,000Litres/day (38m^3/day). Overall, the daily water abstracted from all the water source types for use by humans and livestock was nearly 366,540Litres/day or 366.54m^3/day.

Table 4. Estimated number of community members and livestock using the survyed water sources in Kirisia Forest watershed

Type of water source	Name of water source	Approximate No. of beneficiaries	Approximate water abstraction (jerry cans* per day)	Approximate water abstraction (Liters/day)	Approximate water abstraction (m^3/day)	Approximate No. of livestock using water source
Shallow wells	Loikas shallow wells	9800	4200	**38000**	**38**	12200
	Ntontol shallow well	350	300			9320
	Lorok wells 1, 2 & 3)	1000	1200			2610
	Mean	**3717**	**1900**			**8043**
Earth dams and water pans	Ntontol dam	350	150	**91960**	**91.96**	9320
	Suen dam 1 & 2	6000	7200			12500
	Baawa dam	4000	10800			28020
	Prison dam	14000	6000			7055
	Nondoto dam	1800	1040			40000
	Morijoi dam	4800	2400			6000
	Ngorika water pan	50000	-			5060
	Mean	**11,564**	**4,598**			**15,422**
Boreholes	Partuk 1	40000	25000	**197720**	**197.72**	-
	Leirr borehole	3000	750			20000
	Ngorika borehole	420	420			5060
	Lchoro borehole	948	1476			1160
	Baawa borehole	5062	3311			-
	Mean	**9886**	**6191**			**6555**
Springs and streams	Ngorika springs	420	-	**38860**	**38.86**	5060
	Ngonyeki springs	4900	2100			11180
	Nashuda stream	210	120			6100
	Mean	**1843**	**1110**			**7417**
Total		**147060**		**366540**	**366.54**	**180645**

*A jerry can is equivalent to 20 Litres.

Kirisia Forest watershed is the only source of domestic and livestock water supply for 23 sub-locations in Kirisia and Lorroki Sub Counties (Table 5). According to the 2009 national population census, the total human population in the two sub-counties which includes Mararal town was 92,695 people who can be considered as the watershed beneficiaries. This number is expected to increase to approximately 116,427 people by 2020 and 142,954 people in 2030 (Table 5). Based on the 2009 population census, the human water demand varied among the sub-locations, and ranged from 127,800Litres/day (127.80m^3/day) at Barsaloi to 81,880,600L/day (81,880.60m^3/day) for Maralal town (Table 6). The projected total water demand for all the sub-locations was about 182,238,520Litres/day (182,238.52 m^3/day), and the highest water demand areas were; Mararal town, Ledero, Lpartuk, Loosuk and Opiroi (Table 6). Using the 2013 livestock population data for all the sub-locations, the total volume of water demand by livestock was estimated at 12,172,600Litres/day (12,172.60m^3/day) (Table 6) The highest livestock water demand areas were; Sukuta Marmar, Loosuk, Malaso and Opiroi; and the total water demand by humans and livestock approximately 194,411,120Litres/day (194,411.12 m^3/day.

Table 5. Human population estimate and projections for sub-locations in Samburu Central Sub-County which depend on water from Kirisia Forest watershed

Sub location	2009 population estimate	2020 population projection	2030 population projection
1. Angata Nanyukie	2388	2999	3694
2. Barsaloi	1525	1917	2359
3. Loibashai	1239	1556	1916
4. Loosuk	2756	3462	4263
5. Malaso	2214	2781	3425
6. Opiroi	3115	3912	4818
7. Sukuta Marmar	4173	5241	6455
8. Mabati	1042	1309	1611
9. Mbukoi	1112	1397	1720
10. Nkejemueny	924	1161	1429
11. Seketet	2560	3215	3960
12. Siambu	745	936	1152
13. Sirata Oirobi	1346	1691	2082
14. Ledero	1822	2288	2818
15. Lpartuk	3452	4336	5340
16. Lolmolok	3758	4720	5381
17. Langatolia	1729	2172	2674
18. Mugur	990	1243	1531
19. Milimani	4468	5612	6911
20. Nkuroto	3407	4279	5270
21. Ngari	5027	6314	7776
22. Shabaa	6148	7722	9510
23. Maralal Town	36755	46164	56859
Total	92,695	116,427	142,954

Table 6. Estimated human and livestock population and projected water demand in Kirisia Forest Watershed-Samburu Central sub-county

Sub-location	2009 human population census	Domestic water demand (liters/day)	Domestic water demand (m^3/day)	Estimated livestock population (2013)	Water demand by livestock (Liters/day)
1. Angata Nanyukie	2388	954300	954.30	2800	28000
2. Barsaloi	1525	127800	127.80	1500	15000
3. Loibashai	1239	381700	381.70	10750	107500
4. Loosuk	2756	3075300	3075.30	62100	621000
5. Malaso	2214	1558300	1558.30	59950	599500
6. Opiroi	3115	2138700	2138.70	55330	553300
7. Sukuta Marmar	4173	1133100	1133.10	98700	987000
8. Mabati	1042	183400	183.40	55330	553300
9. Mbukoi	1112	350000	350	1100	11000
10. Nkejemueny	924	604300	604.30	21050	210500
11. Seketet	2560	976800	976.8	33850	338500
12. Siambu	745	1186200	1186.20	55330	553300
13. Sirata Oirobi	1346	1645000	1645	261500	2615000
14. Ledero	1822	49339000	49339	55330	553300
15. Lpartuk	3452	3632600	3632.6	55330	553300
16. Lolmolok	3758	2647100	2647.10	55330	553300
17. Langatolia	1729	5070720	5070.72	55330	553300
18. Mugur	990	5070720	5070.72	55330	553300
19. Milimani	4468	5070720	5070.72	55330	553300
20. Nkuroto	3407	5070720	5070.72	55330	553300
21. Ngari	5027	5070720	5070.72	55330	553300
22. Shabaa	6148	5070720	5070.72	55330	553300
23. Marala town	36755	81880600	81880.60		
Total	92,695	182,238,520	182,238	1,217,260	12,172,600

5. Discussion

A variety of water source types exist in the Kirisia Forest watershed but most of them especially springs, streams, water pans and shallow wells tend to be seasonal. Boreholes, earth dams and some of the shallow wells are more reliable in water provision especially during the dry season due to their permanent nature. Nyaligu (2013) documented a higher variety of water source types (48) in the watershed compared with our study which included; marshes, swamps, springs, shallow wells, earth dams and boreholes. Our survey was done during a prolonged dry spell, and locals mentioned the area had not received adequate rainfall for the last two years or so while that of Nyaligu (2013) was done during the wet season; this may account for the diverse water types reported in his study. The endowment of the watershed with diverse water source types may be attributed to a variety of factors such as; expansive nature of the catchment and its diverse topography and altitude, land cover types like forests, woodlands and bushlands (Hitimana et al., 2011; KFS, 2012; Nyaligu, 2013; Kiringe et al., 2015b). Further, it has an expansive drainage network with the Northern and Eastern zones having the longest and most dense drainage network followed by the Western and Sothern Zones in that order. These attributes coupled with a tri-modal rainfall pattern provide environmental conditions which enhance the hydrological functions of the watershed in terms of rainfall interception and channeling it into the soil, underground aquifer and associated water systems. Consequently, preservation of this environmental heterogeneity is important in sustaining the natural ability of the watershed to harness and replenish water. In a study in the Chyulu Hills watershed which is a dry-land water catchment like Kirisia Forest, Kiringe, Mwaura, Wandera, Kimeu & Gachuga (2015a) documented different types of water sources (springs, shallow wells, rivers and boreholes) and attributed this to the expansive and heterogeneous nature of the watershed.

Kirisia Forest watershed is located in a semi-arid region characterized by water deficit due to low and unreliable rainfall (Watai & Gachathi, 2003; Lambrechts et al., 2005; Anne, 2009; KFS, 2012). Therefore, all the water sources associated with the watershed within it and beyond are key focal points for water use by humans, wildlife and livestock, and are normally subjected to heavy daily water abstraction especially during the dry season. In particular, earth dams and water pans like those found in the watershed are very important water sources in arid and semi-arid areas where rain water is harnessed from surface runoff (RoK, 1991). Normally, pans store water for a short period of up to 3 months after the rains unless they have underground recharge system. On the other hand, dams are designed to store large volumes of water for a long period of time, and in this regard the numerous dams found in the Kirisia Forest watershed are critical and more reliable water supply assets in the region.

Although water dams and pans are supposed to provide water for various uses, their water quality is not guaranteed since most of them are open and easily accessible by humans, livestock and wildlife leading to water contamination. Therefore, other water sources like springs, boreholes and shallow wells are critical in supplying water for household uses since their water is less likely to be contaminated to the extent of making the water unsuitable for domestic purposes. The boreholes found in the watershed also offer a more reliable source of water in the absence of surface water especially during dry periods, and in most cases, their water quality is good and assured unless for cases of salinity and high fluoride levels(RoK, 1991; Nyaligu, 2013;Kiringe et al., 2015b). Generally, boreholes with high water discharge can serve more people and cover larger areas, and are essential water sources especially in dry areas like Kirisia Forest where water resources are scarce in space and time. In their study in the dry-land watershed of the Chyulu Hills, Kiringe et al. (2015a) also found that boreholes were not only prevalent but they provided water to a large population of beneficiaries.

The key beneficiaries of the water provision services associated with Kirisia Forest watershed were pastoral communities living within and in the immediate environs of the watershed mainly for domestic uses and watering their large herds of livestock. Urban populations in centers like Maralal town, Kisima and Sukuta Marmar also depended on water associated with the watershed. However, the diversity of water users in the watershed was much lower compared to that of the Chyulu Hills (Pringle & Quayle, 2014; Kiringe et al. 2015a) included; domestic water users, livestock keepers, small scale irrigators, wildlife conservationists, large scale irrigators and tourism operators. This difference may be attributed to the high water provision capacity of the the Chyulu Hills watershed compared to Kirisia Forest. Documentation of water source types in other dry-land catchments in the country such as Mt, Kulal Forest watershed in Marsabit (Watkins & Imbuni, 2007) and Taita Hills watershed (Eduardo et al., 2011; Johanna, Emmah, Paola & Pellikkaa, 2015) have shown they are also characterized by a low variety of source types like Kirisia Forest.

Most of the water in the Kirisia Forest watershed was mainly used for domestic chores (cooking, drinking, bathing and washing clothes) followed by livestock. Thus, the projected water demand by humans is almost fifteen times more that of livestock although the population of the former is far much less that the later. Humans are physiologically less enduring to low water intake compared to livestock, and also use water for other domestic needs, and as such tend to use more water compared with livestock. In general, the water requirements of livestock is a function of; feed and salt ingested, lactation, size of the animal, animal's genetic adaptation to its environment and ambient temperature (Peden et al.,2003). It's worth noting that water use and demand by wildlife in the Kirisia Forest watershed was not estimated and as such, the estimated water use and projected demand is less than the actual use. Water use and demand for most of Kenya's dry-land water catchments has not been documented but Kiringe et al. (2015a) approximated human and livestock water use in the Chyulu Hills watershed to be 244,238.25m^3/day. In the Taiita Hills watershed (Eduardo et al.,2011; Johanna et al.,2015) documented high water use levels by humans compared to livestock use due to irrigation activities. Watkins & Imbuni (2007) also documented low water use level by humans and livestock for Mt. Kulal watershed in Northern Kenya

The 2009 national population census estimated the human population served by the Kirisia Foest watershed to be 92,695 (KNBS, 2009), and this is projected to increase to about 116,427 and 142,954 by 2020 and 2030 respectively (Kiringe et al., 2015b). This, situation together with a high livestock population will continue to use and demand more water from the watershed which may overwhelm the hydrological capacity of the watershed to sustain such a high abstraction level.This study noted numerous shallow wells and springs which had dried up in the recent past, and which may indicate the hydrological processes in the watershed had declined perhaps due to deforestation and environmental degradation. Kiringe et al. (2015b) found a 55% increase in the built environment in the forest watershed between 1973 and 2015 which might partly be due to increase in human settlements and urbanization. Other factors that have been noted to cause massive degradation of the forest are; illegal settlements in the forest, trampling and vegetation destruction by livestock, wood fuel harvesting, forest fires and illegal logging (Watai & Gachathi, 2003; Lambrechts et al.,2005; Anne, 2009; KFS, 2012). Such changes can lead to decline in ability of the vegetation and the general landscape to intercept rainfall and ultimately lower water recharge in the watershed.

6. Conclusions and Recommendations

Kirisia Forest watershed has diverse water source types which are the oases of life for wildlife, communities living in urban centres and a large population of local communities and their livestock. The surface water sources in the forest are concentrated close to the forest edge while communities living further tend to rely mostly on underground water resources drawn from bore holes and shallow wells and whose water recharge is linked to the forest water catchment. Underground water from the forest is harvested beneath sandy seasonal lagga's, which cautions wildlife, livestock and communities from the adverse effects of water shortage during times of droughts. Communities living contiguous to the forest and locals, domestic and wildlife animals living between Kirisia Forest and the Mathews Range depend almost entirely on water supplied by the watershed. Earth dams, shallow wells and boreholes were the most reliable water sources but wells and dams were more vulnerable to anthropogenic contaminants and runoff during the wet season. Dams were faced by another problem of eutrophication due to defecation by livestock particularly during the dry season when they were heavily used by large herds of livestock. Permanent rivers and springs were very few and most of the drainage system comprised of laggas which had water mostly on a seasonal basis. A notable aspect of the watershed was prevalence of dry water pans, shallow wells and springs in most of the drainage system of the catchment zone. This is a worrisome situation which requires further investigation to understand the possible underlying cause(s).

The watershed was the main water source for many households in 23 sub-locations including a rapidly growing urban population in urban centres like Maralal town and a large population of livestock. Human used the highest amount of water followed by livestock and this is projected to escalate in future. Based on the 2009 census data, the estimated population of the locations was 92,695, and it's projected to increase to 116,427 and 142,954 people by 2020 and 2030 respectively, and this will potentially lead to a surge in water use and demand. Unless effective conservation measures for Kirisia Forest and water management interventions are put in place, trends in water use and demand in the watershed will exceed the available water resources and in the long-term stagnate socio-economic development. Water conflicts among locals and with wildlife are also likely to become prevalence and severe.

Based on the findings of this study, we recommend various strategies that can be used to address the water situation in the watershed. There's an urgent need to enhance protection and conservation of the forest which is the main water replenishment power house in the region. This is not an easy undertaking given the political implications of removing illegal settlers and regulating livestock grazing by local communities but it holds the key to ensuring long-term water provision in the entire watershed. In the same vein it's important to educate and create awareness among different water users and stakeholders on the linkage between water availability and the environmental state of Kirisia Forest, and the importance of embracing sustainable water use ethics. It's also necessary to create an independent and inclusive oversight taskforce to oversee sustainable protection of the forest. Currently, the management of all water towers in the country including Kirisia Forest is under different government lead agencies (i.e. Kenya Water Towers Agency, Kenya Forest Service, Kenya Wildlife Service and more recently Community Forest Associations-CFAs). But this institutional arrangement creates confusion and duplication of oversight responsibility at the expense of ensuring that water towers are effectively protected since they are the main water power houses which drives the local and national economies. Creating awareness among communities living within the watershed on the impacts of climate change on water resources, and training them on how to cope with this change so as to reduce adverse effects on their livelihoods is also essential. There's a need to document and monitor water yield and abstraction in the watershed, and use the data to make informed decisions on effective and sustainable water management. Communities dependent on earth dams, shallow wells and water pans should be trained on how to secure their waters to ensure year round availability of suitable water for domestic uses especially for drinking and cooking purposes. It's also important to have designated watering points for livestock to reduce water contamination by dung.

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