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Multi Reservoir Operation and Challenges of the Omo River Basin: Part II: Potential Assessment of Flood-based Farming on lower Omo Ghibe Basin

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1. INTRODUCTION

1.1 Background

Flood-based farming is a unique form of water resource development and management that uses often unpredictable and occasionally destructive water supply from ephemeral streams for various farming activities. It is climate smart agriculture that can be widely applied for crop production, agro-forest and rangeland management, domestic and livestock water supply, recharging groundwater. Flood-based farming can be expressed through:

- Mainly Spate irrigation – direct diversion of flashy foods in to the downstream command area
- Flood inundation and recession- rivers overflow their embankment and flood adjacent areas
- Flood spreading weirs – direct diversion/storage of flashy foods in to/at the upstream side command area
- Road water harvest – harvesting flood from road culverts to supplement nearby cultivated land.

Flood-based farming systems accounts for over 30 and 15 million hectares across the world and Sub-Saharan Africa respectively. It also supports around 75 million most vulnerable segments of society across the world. Furthermore it covers over one and half million hectares in Ethiopia and Kenya and the potential could even be higher. In Ethiopia, it is widely practiced in areas like the Omo Ghibe River, Raya Valley, Kobo, Fogera/Lake Tana, Baro Akobo, Wabishebele, Upper Awash/Becho Plains, Kokalake, Konso etc. The arid and semi-arid areas of Kenya make up to 80 % of the country’s territory and approximately 30 % of the Kenyan population lives in this region. Muthigani 2011, reports that the spate irrigation potential of Kenya could reach as much as 800,000 ha.

Flood-based farming systems represent a unique option for the management of scarce water resources in support of agricultural production and livelihoods of marginalized populations in many arid and semi-arid parts of the country. Spate irrigation is one of the traditional practices employed by farmers/agro-pastoralists to either as one means of irrigation or to supplement rain fed agriculture. It mainly occurs in areas where flat lands are bordered by mountainous or high land catchments where short duration and peak floods are generated from the catchments in ephemeral streams. These ephemeral streams are also sources of fertile sediments which are characterized by deep and fertile soil suitable for agriculture as a result of ages old alluvial deposition. Spate irrigation is found in the Middle East, North Africa, West Asia, East Africa and parts of Latin America. In some countries it has a long history – more than 5000 years in Yemen, Pakistan and Iran (Van Steenbergen et al., 2011). In Ethiopia, it is practiced in many parts of which the lowland of Omo Ghibe basin is one.

In the valley of the Omo River, the practice of Flood-based farming is limited to flood recession agriculture (Adams, 1992). In a water resources study of the Omo Ghibe River Basin, flood recession is categorized as a land use class associated with the delta of the river, and is also mentioned to occur in narrow bands along the banks of the lower Omo Valley (Woodroofe and associates, 1996). With the developmental interventions along the Omo Ghibe basin, Ghibe I, II and III hydropower development dam projects, the flood recession agriculture might be affected. As a result the agro-pastoralists should cope-up with the change to the flooding duration and events. Downstream of the Ghibe III dam, however, there is a significant area that can generate floods that can be used for flood recession agriculture at the lower Omo Valley. The purpose of this research was, therefore, to find out the effects of the dams on the Flood-based farming systems at the lower Omo Valley.

1.2 Problem Statement

The perception of many people is that floods will continue to cause serious economic and environmental losses. It is reported that flood disasters account for about one third of all natural disasters in terms of their number and the economic losses. Flood and droughts are the world's costliest natural disasters, causing an average $6–$8 billion in global damages annually and collectively affecting more people than any other form of natural disaster (Lampros V., 2009). An example is the flood that had been caused in 2006 in the Omo basin which inundated the Dasenech and Nyangatom Weredas killing 364 people and displacing between 6000 and 10000 in Kuraz District, South Omo. Nearly 3000 livestock are also reported to have perished due to the flooding (OCHA, 2006).

However, if floods are well managed, they can serve as a source of livelihood. In many parts of the lowlands of the Blue Nile countries, flood is the only opportunity where sources (agriculture, hydropower, agro forestry, etc.) of livelihood can be improved. One of the ways of managing floods is building dams. The Omo Ghibe basin, the research study area, is characterized by extensive utilization of flood recession agriculture (one form of Flood-based farming) at its lowlands and delta where the river joins Lake Turkana. The majority of the source of the flood is from the Ethiopian highlands where The Lake is sustained by the inflows of Ethiopia's Omo River, which alone provides 90 % of the lake inflow (S. Avery, 2010).With the upstream interventions of the Ghibe I, II and III already built and under construction; the downstream Flood-based farming could be affected. This research was, therefore, targeting at assessing the impact of upstream developmental interventions on the downstream flood utilization and management of the Omo Ghibe basin.

1.3 Research Questions

The main research questions of this study were:

- What are the existing situations of Flood-based farming in Omo Ghibe basin?
- What are the impacts of upstream water resource development (hydropower dams) on downstream flood utilization?
- What are the future conditions of the Flood-based farming system in the Omo Ghibe basin?

- What is the runoff contribution of the catchment area located downstream of the Omo Ghibe III hydropower dam?

1.4 Research Objectives

The general objective of this research was to evaluate the impact of the upstream interventions on the downstream Flood-based farming practices.

The specific objectives were:

- To identify and document the existing situations of the Flood-based farming system in the Lower Omo Ghibe basin and
- To estimate mean annual flood and Potential spate Irrigable area of lower Omo Ghibe basin.

2. LITERATURE REVIEW

2.1 Overview of Flood-based Farming Systems

The perception of many people is that, flooding is a natural process, which may lead to catastrophic results if it coincides with the presence of a vulnerable object (Embaye and Hiben, 2013). However, flood is the source of livelihood, through flood recession agriculture, spate irrigation, dambo irrigation etc in many parts of the world, especially East Africa and some parts of Asia. It is manly practiced in the Middle East, North Africa, West Asia, East Africa and Latin America. The occurrence of flood related farming systems is often linked to areas that are prone to annual flooding (S.C. Nederveen, 2012). Though the flooding could be catastrophic, it sometimes is the only source of livelihood especially in many lowlands where there is no other source of water for irrigation and or agricultural purposes.

Flood-based farming systems use either the direct diversion of floods from nearby mountains or the residual moisture of seasonally flooded lands when the floods recede. The area that could be irrigated by such kinds of practices varies from year to year depending on the availability of rainfall or flood. They however can be characterized by:

- The floods are unpredictable in timing, frequency and magnitude (Mehari et al., 2005) as a result there is higher uncertainty with respect to determining the area that can be irrigated by flooding. Consequently, farmers around these areas have rich experience in agronomic practices where they plant different crops and varieties that have different tolerance for both excessive and small magnitudes of floods.
- There is excessive sedimentation into the canals and or the command area as the flood coming during rainy seasons carries fertile sediment from the upper catchment that will be dropped in the command area. Furthermore, there is a frequent change of bed level in these areas.

Flood-based farming is the oldest form of agriculture practiced in arid and semi-arid regions for so many years. The best known Flood-based farming systems are found in the Arabian Peninsula, notably in Yemen, where it dates back to 2000 years (UNDP/ FAO, 1987), and the Negev Desert region, which were built during the Israeli, Nabataean and Roman-Byzantian periods going back to 1,300 to 2,900 years (Evenari et al., 1971). According to survey made by Aqua stat (FAO, 2010), there are few countries where Flood-based farming is practiced. No exact estimation is available on the magnitude of Flood-based farming, but the area where it is performed in Africa may exceed 20 M ha (S. C. Nederveen, 2012). But it is believed that, Flood-based farming systems account for over 30 and 15 million hectares across the world and Sub-Saharan Africa respectively. Van Steenbergen et al. (2010) roughly estimate that, global spate irrigation (one form of Flood-based farming) coverage extends up to 3.3 million hectares even though uncertainty and seasonal variability of irrigated land is there and Pakistan has about 1.4 million ha area under spate irrigation, (FAO, 2003). Although spate irrigation is uncertain type of investment economically it is very important practice in countries such as Yemen, Pakistan, Eritrea and Ethiopia where agriculture is a vital component of their economy (Ratsey, 2011).

2.2 Flood-based Farming Systems of Ethiopia and Kenya

Ethiopia is endowed with huge potential of Flood-based farming systems especially for spate irrigation and for flood recession agriculture. Spate Irrigation is practiced in many parts of Ethiopia where the area served by spate irrigation currently is estimated at around 140,000 ha (Alemehayu T., 2008) and is growing by 20,000 to 40,000 ha/yr (Embaye et al, 2012). The dominant regions in Ethiopia where spate irrigation is practised include the southern part of Tigray (the Raya Valley, there is a potential of 80,000 ha of land to be irrigated by flood- farming by the total runoff of about 170 Mm^3/yr/annum generated from the highland catchments (Eyasu, et al., 2013), Afar, Eastern Hararghe, Nazareth, Konso and the area north of Lake Stephanie (near Jinka) (Embaye et al, 2009).

Furthermore, according to S. C. Nederveen (2012) flood recession agriculture in Ethiopia is practiced around Lake Tana, Baro-Akoba, Omo Valley, Wabi Shebelle, Upper Awash. Seasonal swamps and wetlands are also available within Gelana, Denakil and Tekeze River Basins. The land use inventory made by the Woody Biomass Inventory and Strategic Planning Project (WBISPP, 2002), also indicated that, the location and occurrence of different types of wetlands in Ethiopia, estimate suggesting the total extent of wetlands in Ethiopia to be around 1.5%. According to the inventory, flood recession areas are often classified as wetland areas and the spread of the wetland area gives an indication where flood recession farming occurs. According to S. C. Nederveen et.al, 2011, Flood-based farming (flood recession agriculture) practice in Ethiopia is associated with wetland areas where the total area in Ethiopia is estimated to be more than 1.65 Million ha where Amhara and Oromia are endowed with 0.43 Million and 0.4 Million hectares of land respectively.

Teka D. et al. (2014) have estimated the Flood-based farming potential of Afar, Amhara, Oromia, Benshangul Gumuz and SNNP regions of Ethiopia. Accordingly,

- Afar region has a total area that can be irrigated through Flood-based farming is close to 108,000 ha.
- In Amhara, around 1,079,588 ha is considered as suitable for Flood-based farming
- In the Benishangul-Gumuz Regional State there is a potential of 99,300 ha of Potential.
- In Oromia region, close to 2,557,172 ha is considered as suitable for Flood-based farming.
- SNNP region, close to 773,000 ha is considered as suitable for Flood-based farming practices.

Another study undertaken by Hiben et al. (2014) shows that the Flood-based farming potential of the Tigray region is estimated to be 661,854 ha where 80,000 ha is located in the Raya valley.

According to Muthigani, 2011, the spate irrigation potential of Kenya could reach as much as 800,000 ha. Some of the spate irrigation systems in Kenya include, the PokOmo and Marakote people along the Tana River, over flow from Daua River along the Kenya Ethiopia boarder is used in areas of Rhamu, Rhamu Dimtu, Malka-Mari, Harere. Over flow from the Tana within the immediate flood plains that extends about 2 to 5 Km provide adequate moisture for crops grown after the flood event and the Marakwet in Northern Rift Valley in Kenya.

Another study undertaken by Eyasu et al., (2014) in Marsabit and Turkana counties indicates that, there is a Flood-based farming potential,

- ChafaBalal, Garba, Loglogo, Ariya and Kargi is 107,698, 6424, 2895, 2815 and 815 ha respectively in Marsabit county and
- Nakatwan, Kobuine, Kalapata, Kaapu and Natira/Lokipoto 518, 95, 90, 84 and 71 ha of land in respectively in Turkana county.

2.3 Flood-based Farming Systems Practice in Omo Ghibe Basin

The Omo Ghibe basin is endowed with an annual water resource potential where, the average annual outflow from the basin into Lake Turkana is about 16.6 Mm^3 and a total ground water potential that may be developed is estimated to be 1 Bm^3/year (MWIE, 2014). It is also endowed with a suitable land potential of 3 M ha, 2.3 M ha, 0.35 M ha and 3.8 M ha of land that suits for rainfed small holder cultivation, mechanized rainfed farming, Irrigation and forestry respectively (MWIE, 2014). The same author describes that, the potential for irrigation by harmonizing both land and water resources is estimated to be only 90,000 ha but this estimate does not include the Flood-based farming potential of the basin, it only estimates the potential of the conventional irrigation systems.

The type of Flood-based farming which is extensively utilized along the narrow strips of the Omo River is, flood recession agriculture where these areas are irrigated by over flooding of the banks and river deltas. According to S. C. Nederveen, 2011, the total area under flood recession is set at 11,037 ha, but this includes riverine woodlands, open bush land and bare soil as well. In a water resources study on the Omo Ghibe River Basin, flood recession is as a land use class associated with the delta of the river, and is also mentioned to occur in narrow bands along the banks of the Lower Omo Valley (Woodroofe and associates, 1996). The fluctuation of the flood size over the years makes it difficult to precisely quantify the flood recession area, but it is estimated that 100,000 people depend on the system (Woodroofe and associates, 1996).

Farming practices in the highlands significantly vary from those in the lowlands where mixed system with cereal crop domination and cultivation using oxen is practiced in the highlands and Maize, sorghum and millet are the main crops grown in the lowlands which are planted on the river banks of the Omo River as the annual flood recedes (S.C. Nederveen, 2011). Other cereals, pulses, enset, and faba beans are also grown using a traditional hoe-cultivation. In the lowlands particularly, in the lower Omo, agro-pastoral groups practice cropping on the river banks using traditional hoe for cultivation after the flood is receded.

2.4 The Role of GIS and Remote Sensing in FBFS Potential Determination

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on site observation (Levin, 1999). It states to the use of satellites to detect and classify objects on earth. Hence, it plays a vital role in rainfall-runoff modeling, especially in acquisition of data in the different aspects of topography, land use, soil cover, slope and which are essential parameters in the field of runoff estimation of a given watershed (Dhawale, 2013). Geographical Information Systems (GIS) is computer-based software, which is used for capturing, storing, querying, preparing, managing, manipulating, analyzing and presenting geographically referenced data (Huisman and Rolf, 2009). GIS integrates the use of hardware, software, data and GPS to unveil geographically referenced information. It also provides efficient tool for data input into data base, retrieval of selected data items for further processing and software modules which can analyze/manipulate the retrieved data in order to generate desired information on specific form (Kumar et al., 2010).

GIS in rainfall-runoff modeling comprises two steps. The first step is to determine hydrologic parameters/ inputs such as

- Slope, flow direction flow accumulation streams and catchment area using a digital elevation model (DEM) and
- Land use, land cover, soil, etc. through digital analysis of satellite image data and observations.

The second step is therefore to undertake hydrologic modeling within GIS environment which is using the SCS model. In the absence or limitations of the stream flow data, which is common in arid and semi-arid areas, the runoff volume estimations should be undertaken using rainfall-runoff relationship developed by United States Department of Agriculture (USDA) soil conservation service (SCS method). This model is basically developed, after several experimental results, for undertaking runoff estimates in un-gauged catchments. This model depends on Curve Numbers.

The curve number method is the most commonly used method for estimating the volume of runoff generated for every rainfall drop. The CN for each soil type and land use/cover dictates the expected maximum storage of the soil, S. In the SCS-CN method runoff starts after initial abstraction Ia (interception, depression storage and evaporation) has been satisfied. This abstraction comprises principally the interception, surface storage, and infiltration. The ratio of amount of actual retention to the maximum storage is assumed to be equal to the ratio of actual direct runoff to the effective rainfall (total rainfall minus initial abstraction).

Equation (1) shows the assumed relationship in the following mathematical equation.

$$\frac{P - I_a - Q}{S} = \frac{Q}{P - I_a} \text{............ (Equation 1)}$$

Where: P is total rainfall (mm);

Ia is initial abstraction (mm);

Q is actual direct runoff (mm); and

S is watershed storage (mm).

In the above equation, both parameters (Ia and S) need to be estimated. To eliminate the necessity of estimating both parameters, the relation between Ia and S was developed by analyzing rainfall-runoff data for many small watersheds (CSC, 1972). Generally, Ia is considered to be 20 % of the maximum soil storage, S (Equation 2).

$$\mathbf{I_a = 0.2\ S} \text{ .... (Equation 2)}$$

Substituting Equation (2) in Equation (1) gives:

$$\mathbf{Q = \frac{(P-0.2S)^2}{P+0.8S}} \text{ .... (Equation 3)}$$

Equation (3) is the rainfall-runoff equation used by the SCS method for estimating depth of direct runoff from storm rainfall. The parameter S in Equation (3) is related to CN by:

$$\mathbf{S = \frac{2540}{CN} - 25.4} \text{ .... (Equation 4)}$$

The storage parameter (S) varies spatially, due to changes in soils, land use/cover and slopes and temporally due to changes in soil water content. As such, the CN method is able to reflect the effect of changes in land use/cover on runoff.

After computing the depth of direct runoff, the weighted runoff depth will be estimated for the watershed for selected daily rainfall events, using Equation (5).

$$\boldsymbol{Q_{av} = \frac{\sum Q_i A_i}{A}} \text{ .... (Equation 5)}$$

Where: Q_{av} is weighted runoff depth,

Q_i is runoff depth for each polygon (mm);

A_i is polygon area (km^2) and

A is watershed area (km^2).

3. METHODOLOGY

This section clearly presents the materials and methodology which are used in this study. It starts with the description of the study area such as its location and size, population and farming practices, climate, physiographic conditions and soils. It will then follow to describe the development of the methodology. The methodology is comprised of three main phases of which: Phase I is Pre-field work data collection, Phase II is primary and secondary data collection, organization and analysis and Phase III is post field work model build up and analysis. Finally, the section also discusses about the materials used to undertake the study. The detail of each section is discussed hereafter.

3.1 Project Area Description

3.1.1 Location and Size

The Omo-Ghibe River Basin is located in South-West part of Ethiopia, between 4°00' N and 9°22' N latitude, and between 34°44' E and 38°24' E longitude. It is the second largest basin of the country, covering an area of approximately 79,000 km^2. It is drained by two major rivers, the Ghibe River flowing southwards and Gojeb River flowing eastwards. It is an enclosed river basin that drains into Lake Turkana, Kenya (located 3°35'N 36°7'E), which is its southern boundary. It is bounded by the Baro-Akobo Basin in the west, the Blue-Nile Basin in the north and northwest and small area in the northeast bordered by the Awash Basin and the whole of the eastern side borders is the Rift Valley Lakes Basin (Woodroofe and associates, 1996).

Within the basin, there are three large scale hydropower plants namely Gilgel Ghibe I dam (located at 7°49'53''N 37°19'18''E) Gilgel Ghibe II diversion tunnel (located at 7°45'25''N 37°33'44''E) and Gilgel Ghibe III dam (located at 6°50'50''N 37°18'5''E). The three hydropower stations have the capacity of generating 184 MW, 420 MW and 1870 MW respectively. The catchment area of the Gilgel Ghibe III hydropower dam project is 34,150 km^2 representing 43 % of the total catchment area and contributes 80 % of the basin flow. The long term mean flow at

Ghibe III site is estimated to be 435 m^3/s or 13.5 Billion m^3/yr. Seasonal variations are extreme, mean monthly flow ranges between 60m^3/s in March and 1,500 m^3/s in August (WWDSE and SDCSE, 2013).

Furthermore Kuraz, large scale sugar cane development project, (located 06°17' 03" N and 36° 02' 35"E) is also located within the basin. After Ghibe III dam major tributaries of Omo like Guma, Zigna, Mensa and Denchiya join at the right side, while Deme, Zage and Irgene joins to the system at the left side (WWDSE and SDCSE, 2013). This project will irrigate a net area of 150,000 ha on both left and right banks of the Omo River for sugar cane plantation purposes with seven sugar cane processing factories proposed to be established.

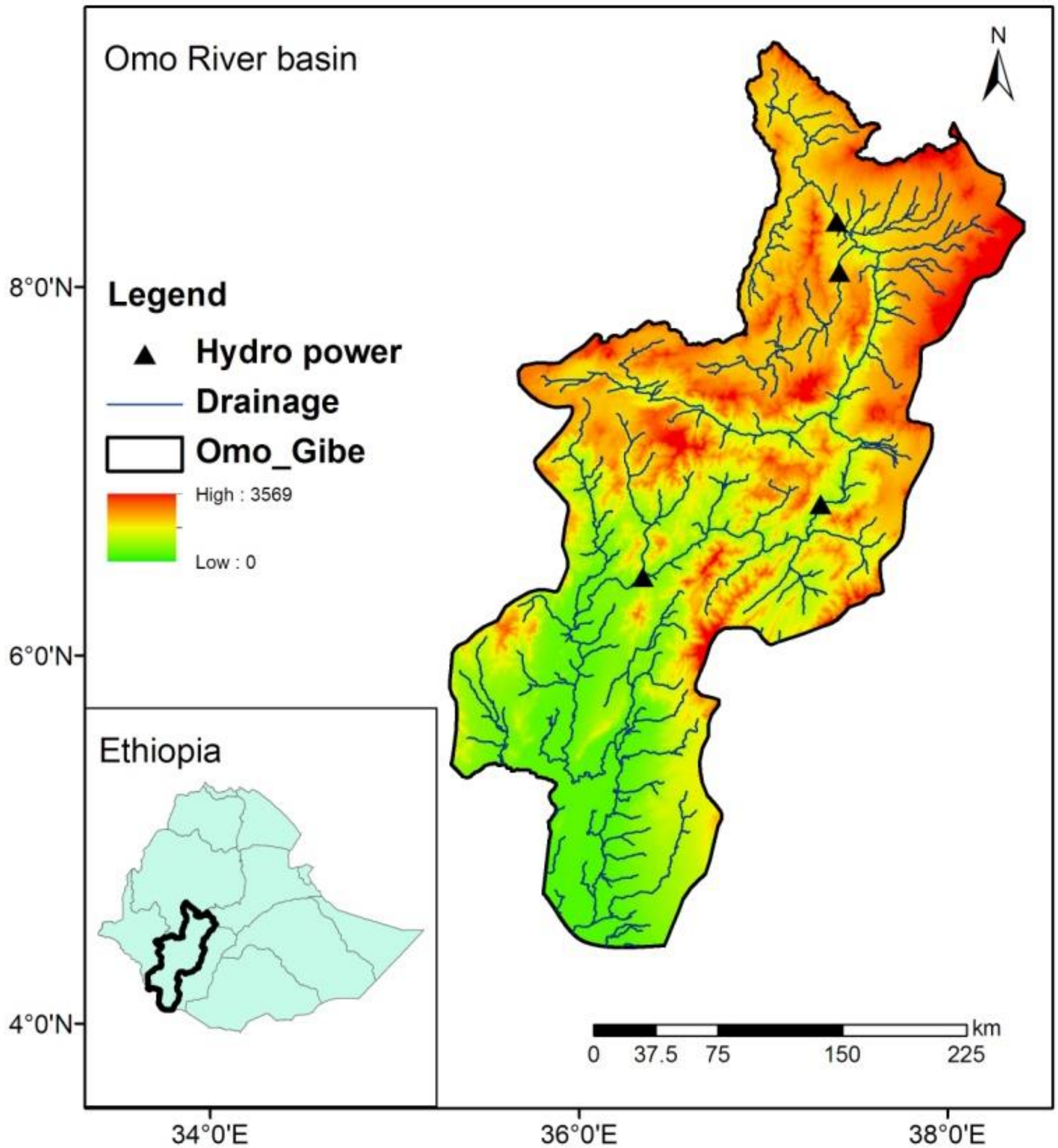

Figure 1.Omo Ghibe River basin

3.1.2 Population and Farming Practices

The population of the basin was 6.4 million in 1994 and about 50.3 % of it was female and about 5 % and 2.9 % of the total population live in the lowlands and in urban areas respectively (MWIE, 2014). Currently, the population of the basin is more than 14 million (CSA, 2007). The basin's labour force of the economically active population is about 2.8 million, representing 43.6 % of the total population (MWIE, 2014).

Table 1 Population of the Omo Ghibe basin

S.no	Zone/Wereda	Region	Urban Population	Rural Population	Total
1	Bench Maji	SNNPR	75241	577290	652531
2	South Omo	SNNPR	43203	530232	573435
3	Hadiya	SNNPR	134041	1097155	1231196
4	Keficho Shekicho	SNNPR	99263	974767	1074030
5	Kembata Alaba Tembaro	SNNPR	97797	583040	680837
6	Semen Omo (Dawuro)	SNNPR	35044	454533	489577
7	Welaita	SNNPR	172514	1328598	1501112
8	Gurage	SNNPR	119822	1159824	1279646
9	Yem Special Wereda	SNNPR	7952	72735	80687
10	East Welega	Oromia	189201	1123995	1313196
11	Jimma	Oromia	371945	2564686	2936631
12	West Shoa	Oromia	293820	1958291	2252111
	Total		**1,639,842**	**12,425,146**	**14,064,988**

Source: Extracted from CSA 2007

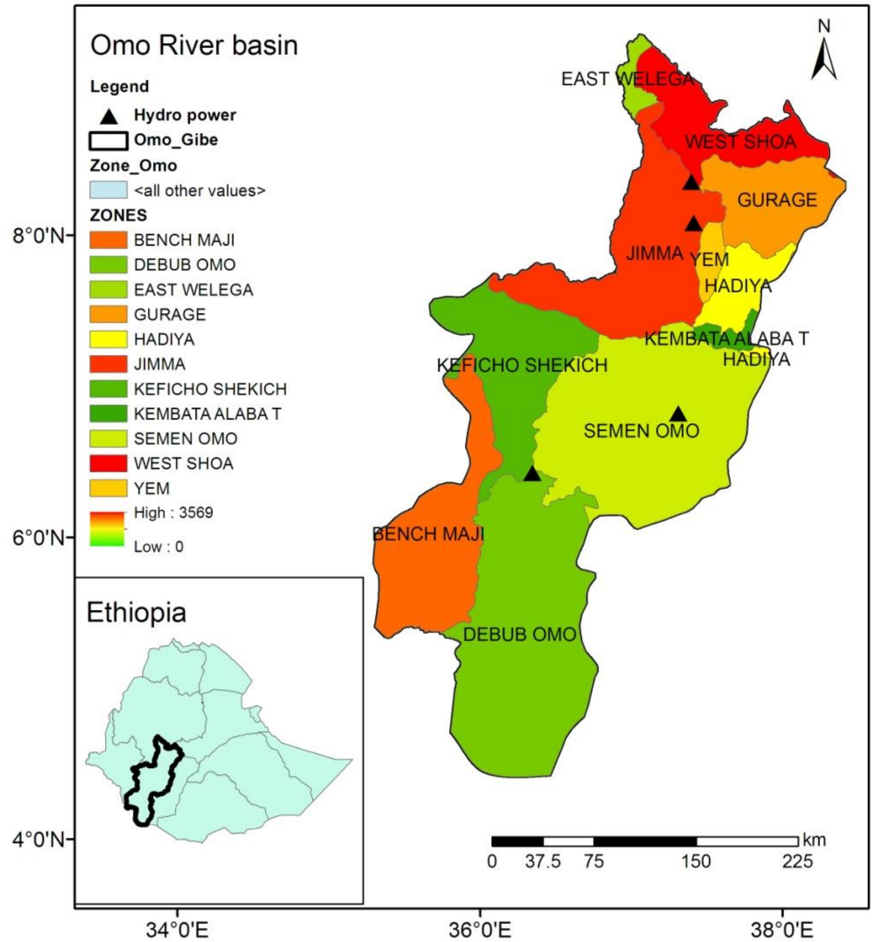

Figure 2. Zones of the Omo Ghibe basin

Smallholder, State Farms, private commercial ventures and NGO-sponsored agriculture development practices are found in the basin where smallholder farms cover over 98% of the total cultivated land (MWIE, 2014) and most of the agricultural production is rain fed. The farmers in the project area (mainly on the high land) produce small quantities of a wide range of crops (as many as 15-20 different crops), including cereals such as maize, sorghum and barley, roots, tubers, pulses, spices, coffee and fruits (EEPCO, 2009) and Livestock are complimentary to crop production system. In the lowlands particularly, in the lower Omo, agro-pastoral groups practice flood-recession farming, where the land is cultivated using traditional hoe.

3.1.3 Physiographic Conditions

The Omo Ghibe River Basin is drained by two major rivers from the highlands, the Ghibe River flowing southwards and Gojeb River flowing eastwards (WWDSE and SDCSE, 2013). The Ghibe River is called the Omo River in its lower valley south and south westwards from its confluence with the Gojeb River. The northern part of the basin has a number of tributaries from the northeast of which the largest are the Walga and Wabe Rivers. The Tuljo and Gilgel Ghibe Rivers are important rivers that drain to the Ghibe.

Many of the rivers rise in plateau areas at an elevation above 2000 m.a.s.l. and parts of the watershed are higher than 3000 m.a.s.l.. To the west of the river basin the watershed reaches an elevation of 3000 m.a.s.l.. between the Gojeb and the Gilgel Ghibe River. The width of the river in the lower reach during flood time may vary from 800 m to 3 Km and the river depth is around 4 - 30 m (WWDSE and SDCSE, 2013). Thick densely grown brushwood and bushes dominate the over-flooded area.

Figure 3. Flooded area near Omo Rate, September 2014

Figure 4. Flood Inundation in Gnangatom wereda near Kangaten town, September 2014

Source Mr. Tenaw Endalamaw

As can be seen from the figure below, the majority of the basin area has a slope range of greater than 15 % and the Omo River has an average slope of 3 m/km. Bench terracing based agriculture is also practiced in the basin near Konso. Furthermore, Neykeya Village Spate Irrigation Scheme is also under design phase by the IGAD-INWRM program.

Figure 5. Bench terracing based agriculture in Konso, September 2014

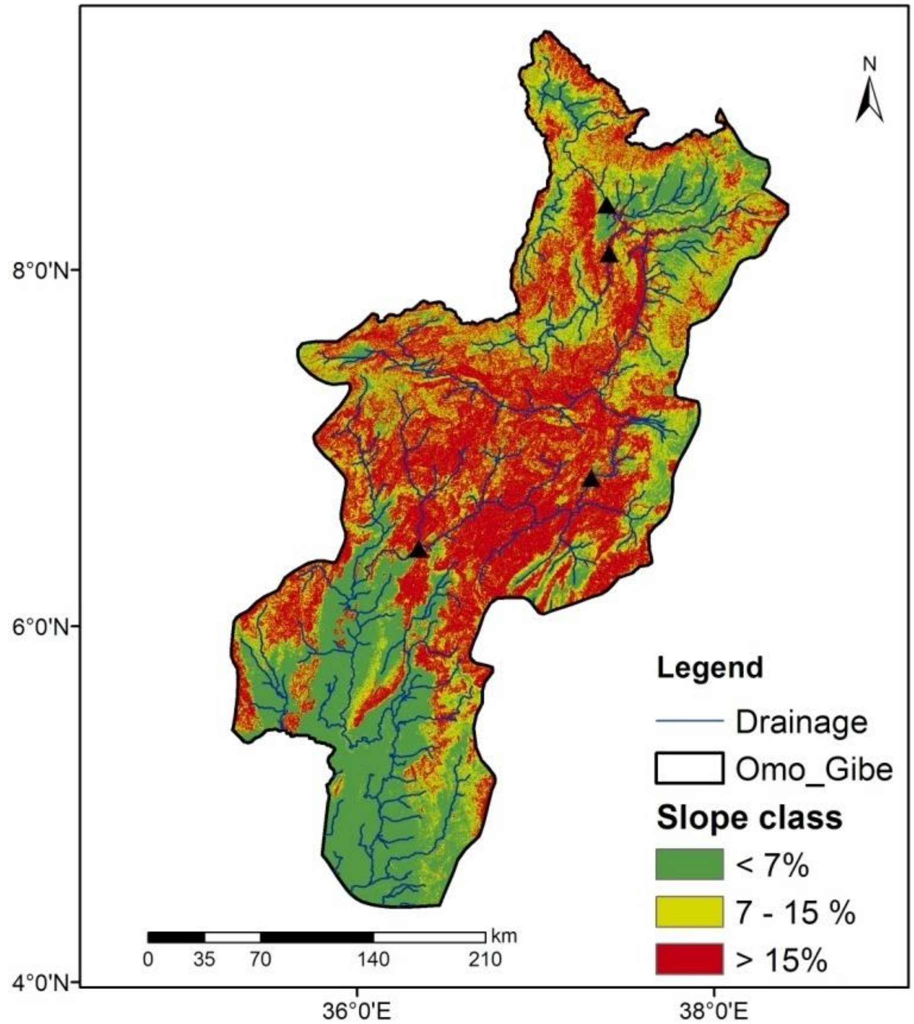

Figure 6: Slope class at the Omo River Basin

Soil erosion is also serious problem in Gilgel Ghibe watershed. The total soil loss into the Omo river from landslide is estimated as 11 t / ha/ yr for the last 20years, therefore, landslides need to be point out as an important sediment source for rivers in the Gilgel Ghibe catchment (PHE Ethiopia Consortium and Jimma University, 2010). As sited by the same author, direct measurements of sediment transport on the Gilgel Ghibe carried out by ENEL/ELC association in May 1996 in correspondence to the dam section with a flow of 25 m^3/s. There is high variation among catchments in specific sediment yield (SSY) due to the variation in the catchments characteristics in the Gilgel Ghibe catchment and it has the low SSY (0.43 t/ha/yr) (PHE Ethiopia Consortium and Jimma University, 2010)

3.1.4 Hydrology and Climatology

The basin divides sharply and almost exactly into highlands in the northern half which are characterized by steep slopes and altitudes reaching up to 4200 m.a.s.l. and lowlands in the southern half which are characterized by relatively gentle and undulating slopes and altitudes as low as 500 m.a.s.l.. The northern highlands are deeply separated and drained by the Ghibe and Gojeb river systems merging to form the Omo in a deeply entrenched gorge (MWIE, 2014).

The climate of Omo river valley varies from tropical humid in the highlands that includes its northern part to the hot arid climate in its southern parts of the flood plain. Intermediate between these extremes and for greater part of the basin the climate is tropical sub-humid. As climate in the country, is associated with altitude, the highlands have colder temperature (around 17 ^{0}C) and sufficient rainfall reaching up to 1900 mm/yr in the northern and western part of the basin, the lowlands however, have high temperature (around 29 ^{0}C) and low to medium rainfall which does not exceed 300 mm/yr near Lake Turkana (WWSDE and SDCSE, 2013).

The average rainfall over the lower Omo (especially downstream of Ghibe III) is as presented in Table 2, and the average rainfall on this part of the basin is 1081.5 mm.

Table 2. Aerial rainfall distribution over the lower Omo basin

Segment of the basin	Slope class (%)	Mean annual rainfall (mm)	Area (km^2)
Lower	<5	720.6	15918.09
Middle	5-15	1,192.0	9135.56
Upper	>15	1,401.0	14796.35
Total			39850

The average annual outflow from the basin into Lake Turkana is about 16.6 Bm^3 (Woodroofe and associates, 1996) although it is reported as 19 Bm^3 on GIWA 47 Regional assessment report (UNEP, 2004). Downstream of the confluence of Tuljo and Gilgel Ghibe Rivers only minor tributaries join, as the river continues southwards and enters the deep gorge where the Ghibe III dam site is located. At the dam site, the catchment area is around 34,200 km^2 that represents 43 % of the total catchment area and contributes 80.5 % of the flow. According to WWDSE and SDCSE (2013), the long term mean flow at Ghibe III site is estimated to be 435 m^3/s or 13.5 Billion m^3 per annum, where seasonal variations are extreme, with monthly mean flow ranging around from 60m^3/s in March to more than 1,500 m^3/s in August.

3.1.5 Soils

Soils in the basin are deep and having high variability in both ways: laterally and vertically. The soils in the highland areas are dominated by deep to very deep red, and reddish brown clay loam overlaying clays and are well drained (MWIE, 2014). The soils are dominantly clay, often vertic but with pockets of sand soils and sandy layers characterized by poor drainage and salinity problems (Endalemaw, 2015). The higher areas to the east are dominated by shallow to deep sandy and infertile soils (Woodroofe and associates, 1996). All these soils have moderate fertility and are dominantly cultivated (MWIE, 2014). Many areas in the basin are not suitable for irrigation because of their steep slope. However, the lower Omo area is flat and moderately suitable soils with frequent flooding from the Omo River (Woodroofe and associates, 1996).The lowland soils are shallow; coarse textured (Eutric Leptosols and Regosols) with moderate to high fertility status (MWIE, 2014). According to FAO, 1998 the soil and Terrain Data base for North Eastern Africa soils, the Omo basin is classified as follows.

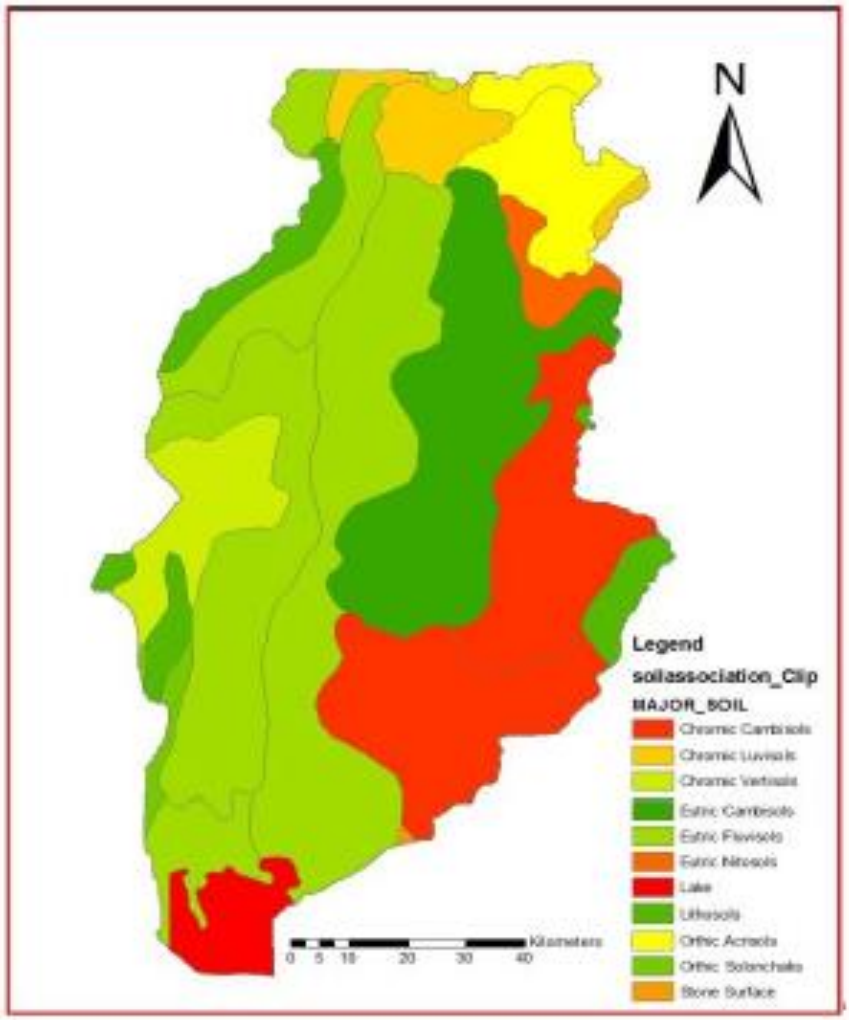

Figure 7. Major Soils of Lower Omo Ghibe basin extracted by Endalemaw, 2015

3.2 Methods

The methodology followed for the research work encompasses three main phases to come up with the required result. These are pre-field work, field work and post field work as stated below.

Pre-field work- the following different tasks had been executed during this phase

- Literature review of documents including previous works
- Extraction of the surface water divide and preparation of drainage map of the study area from DEM using Arc GIS
- Extraction of soil data and land use land cover from satellite images
- Collection and preliminary analysis of data related to existing water resource developments (for hydropower generation and irrigation development purposes) such as Ghibe I, II, III and Kuraz Sugar cane Irrigation Development scheme.

Field work- this is the main phase of the research work and it includes verifying and up grading of the secondary data through cross checking with the field conditions and conducting detail field investigation in the basin. During this phase, the following activities had been done:

- All necessary data such as rainfall, evaporation, basin size, land use type, available flow in the river course, etc had been collected and/or analyzed.
- Different kinds of consultation like interviewing using questionnaires had been conducted with communities, governmental and non- governmental bodies.
- Physical observation of the basin in different location like upstream and downstream areas and collection of coordinates using GPS to be analyzed during the office work.

Post-field work - the activities carried out during this stage include:

- Processing and analyzing of the primary and secondary data collected during the pre-field stage and fieldwork period in order to fit the data input requirement of the ARC GIS model. For data processing purposes, GIS tools were used to prepare input data.
- Building up of the Arc GIS Model to determine the water and land resources potential suitable for Flood-based farming of the basin.
- Analyzing the model results and verification of the results with ground truth. In the analysis relevant information had been taken from the review of previous works in the

area and literature review from similar documents had been compared with the findings in the field work.

- Organizing and compilation of the field data and writing and describing to prepare a report.

A summary of the research approach is as indicated in figure 8.

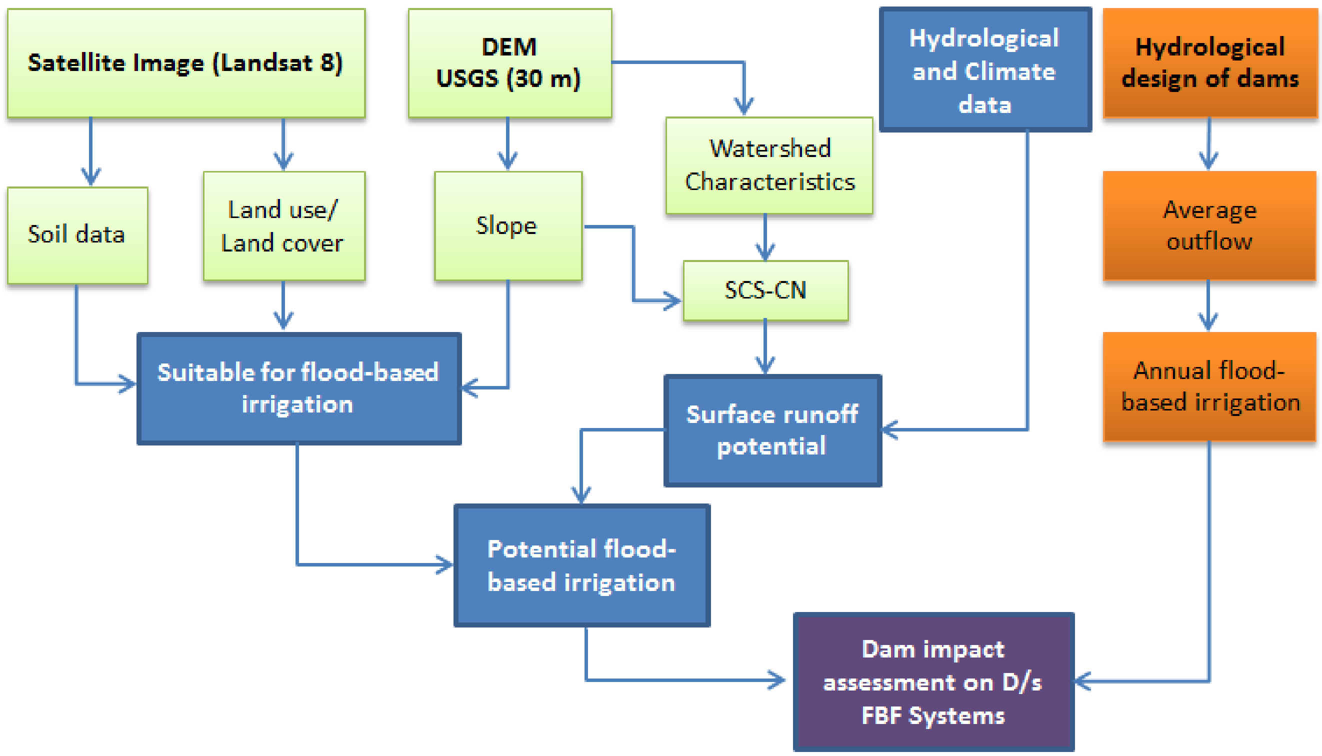

Figure 8.Methodology flow chart

3.3 Materials

Materials which were used to undertake the research are:

- DEM (30 m resolution)
- Topographic maps of the basin
- Satellite images (Land Sat 8)
- Hydro-metreological data (rainfall and river flow discharge)
- GPS to select representative ground observation and sampling points

- ARCGIS software
- Digital Camera
- Field cars
- Google Earth

4. RESULTS AND DISCUSSION

4.1 Impact of Flooding

The Omo Ghibe Basin is one of the most important water resource basins in Ethiopia as it carries close to 13 % of the annual surface water resource of the country, next to Abay and Baro-Akobo. Moreover, the basin is one of the largest hydropower potential next to Abay. Despite these huge resource potentials, the Ethiopian people in general and the people at the basin in particular so far benefited little. The people around the Omo Gibe in general and downstream of the Omo River in particular still continue to practice traditional recession flood agriculture for crop production. Furthermore, the Omo river basin suffers frequent flooding that will affect crop production for significant period of time during the year. According to Endalamaw (2015) a maximum of 19,000 ha in the lower Omo valley will be inundated for a depth of 2.5 m during the maximum peak flow. Moreover, the people are exposed to Malaria, different waterborne diseases, and benefited little from the economic development the country recorded in the last few years. There are, however, important question one has to raise: “how long they continue to survive sawing handful of seeds along the bank of the rivers?” Still they need to change and they also should change their life to a better way of living. Moreover, the country should benefit more from the immense natural resources of the basin at economic scale.

Several studies indicated that the lower Omo valley has experienced repeated flood hazardous (EEPCO, 2009; Endalamaw, 2015). In the eye of these treats and the need to make benefit of the huge water resource of the basin, the Government of Ethiopia has embarked on the basin level master plan studies. As one of the top solutions, construction of dams is implemented. However, according to some, it seems as if the construction of the dam will affect the indigenous people and disrupt the ecology of the basin. Avery (2010) indicated that those dams in the Omo river valley will have simply significant negative effect on the livelihood of the lower Omo valley.

4.2 Flood-Risk Mitigation Measures

The Ethiopian government's policy is to efficiently utilize the Omo River in order to support national development. Realizing this huge untapped potential and the challenges the River Omo pauses on the local people, the government of Ethiopia has embarked on the construction of several series of hydropower projects. These dams are multi-purpose; primarily for hydro-power generation and also for flood protection of the lower Omo valley. However, such an approach has raised concern from some environmental advocates, especially because of the trans-boundary nature of the river Omo. As indicated by EEPCO (2009) the construction of the hydropower dams along the Omo river basin will have less significant impact on the traditional recession farming practice.

Avery (2010) noted that whilst the annual volume is reported to be much the same, about 67 % of the annual runoff volume reaching Lake Turkana will be controlled by Gibe III. The graph (Figure 9) however, indicates that the dam will have insignificant impact on the downstream side, as the total volume runoff generated with and without the project are very comparable. It is only shifting the periods of filling and releasing. Even the mean peak runoff reduction, which can occur in July, though is close to 30 %, will not affect the volume of inflow towards the lake as it is counter balanced by the mean peak increments in the months of January to May. Avery (2010) has also reported that, the annual influx required to sustain Lake Turkana is 19 km3/yr. This magnitude should be further investigated through water balance calculations of the lake as this study could not look into it.

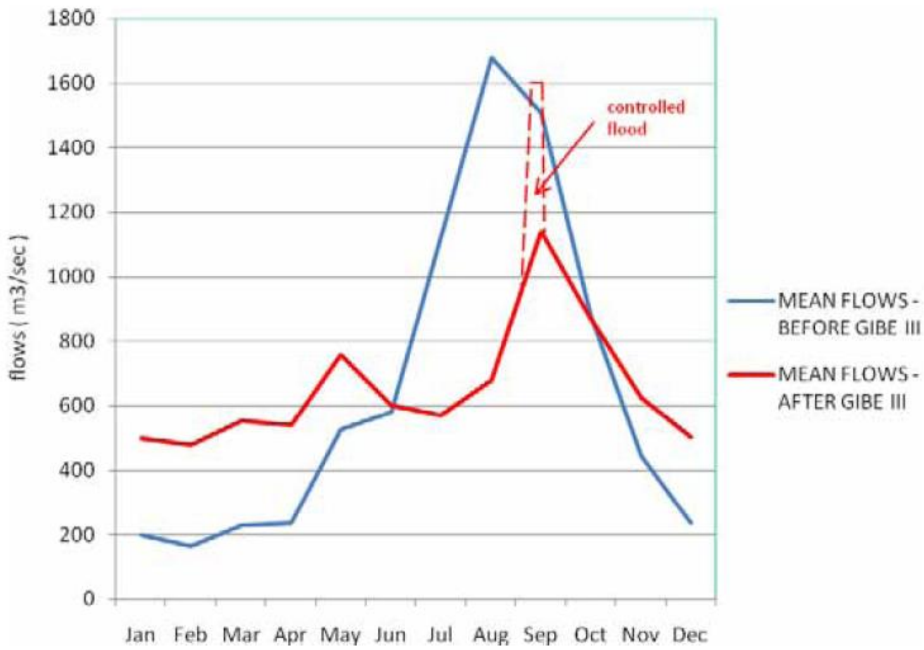

Figure 4.3: Monthly flows at Lake Turkana: average 1964-2001

Figure 9: Mean monthly discharge of Omo before and after Gilgel Ghibe III dam (Source: EEPCO, Agriconsulting et al., 2009)

As indicated by the EEPCo (2009), the existing traditional recession farming practice is mostly practiced along the stripe of the river bank (Figure 10). Endalamaw (2015) indicated that flood recession farming is practiced in the lower Omo Ghibe along the river bank to cultivate Maize and Sorghum. He also noted that all the land is not used for crop production as the local people are pastoralist and agro-pastoralists. Taking into account the size of the existing traditional recession farming and the fact that dam construction won’t have an impact on the river flow (as indicated above), regulated flow from the Omo River will have significant positive impact on the livelihood of the local people.

Figure 10: Traditional recession farming along the strip of the river bank (Source: Environmental and Social Impact Assessment of the GGIII report, 2009).

According to Arsano (2007) building on what already exists, such as through creating community of interest and establishing and expanding many more areas of interaction will provide a significant contribution towards making the riparian countries' permanent partners rather than misguided adversaries. World Bank (2006) indicated that in order to strengthen the water resource development in Ethiopia, it is important to invest in the infrastructure development to provide storage and regulate river flows and runoff. To mitigate against the economic impacts of water shocks in Ethiopia, greater water storage capacity, both natural and manmade, large scale and small scale, will be needed.

From the above discussions, it can be seen that, the construction of dams can boost the Flood-based farming in the basin.

4.3 Flood-based Farming Potential

The basin has one of the largest potential irrigable areas next to Abay. The potential Flood-based farming system command area is estimated as 1.5 million ha (Figure 11). It is important to change the dependency alone on the traditional recession flood farming to other forms of farming practices especially that of modern spate irrigation farming practices to maximize the virtual water available for agricultural development. This could be achieved, among others, if the runoff is regulated. It is believed that the ongoing construction of the hydropower will provide regulated flow sufficient to meet Flood-based farming more than the traditional farming area.

Endalamaw (2015) indicated that flood recession farming is site specific and based on only the experience of the farmers. Though there are a variety of techniques that the farmers adopt to cultivate flood prone area, the farmers are subject to frequent flooding. Moreover, this flood recession farming is practiced along the river banks. He indicated that under the maximum flow period (i.e. 2006), the inundation area is close to 19,000 ha and under regulated flow from the hydropower dams the area that can be inundated is close to 11,000 ha. However, this extent of inundation is estimated taking into account bank breach and with the provision of proper heads, through river diversion or pressurized irrigation system, the area that can be irrigated through flood-based farming can be substantially high.

According to Teka et al (2014) the total potential of spate irrigation in the Southern Nations, Nationalities and Peoples' region of Ethiopia, is close to 772,419 ha. Towards this end, the construction of dams will provide regulated flow throughout the year with the peak runoff able to sustain recession Flood-based farming. Awulachew (2007) indicated that based on the Ministry of Water Resource data the total irrigable area of the basin is close to 68,000 ha. On the other hand Sogreah (2010) categorized the total potential irrigable area as 5,000 ha is "highly suitable", 60,000 ha is "moderately suitable", and 14,000 ha is "marginally suitable".

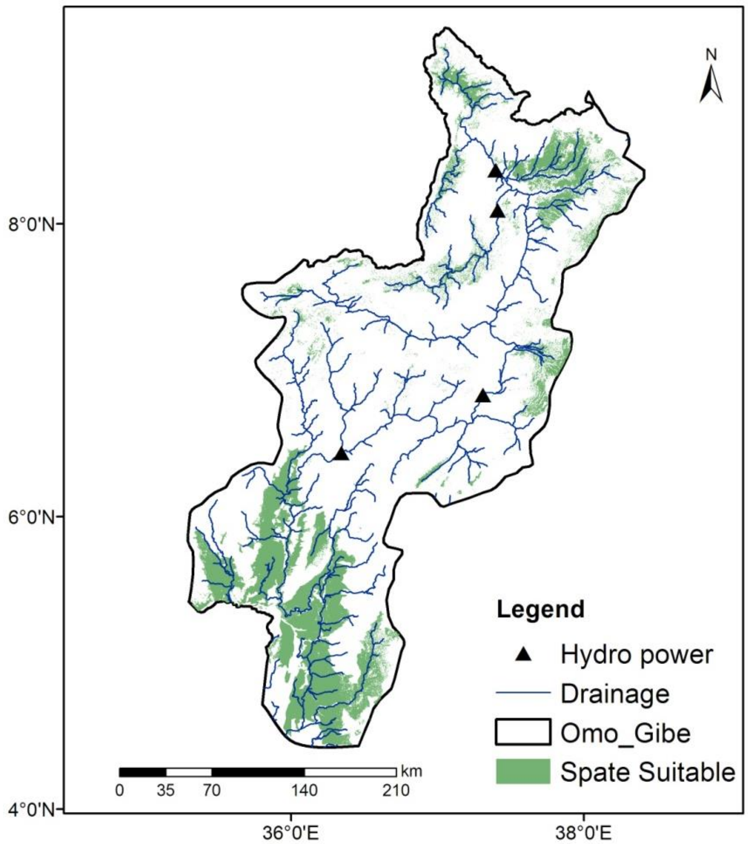

Figure 11: Suitable area for spate irrigation in Omo basin

4.4 Water Resources Potential for Flood-based Farming

The annual runoff potential of the lower Omo valley (i.e below the Gibe III dam) is estimated as 8.19 km^3 using the Rational Method. It is also computed to be 3.1 km3 based on the SCS-CN method (equation 3) indicating an annual runoff depth equivalent to 77.08 mm. The major land use of the lower Omo valley is Silvo-pastoral and the major hydrologic soil group (HSG) is D (Figure 12).

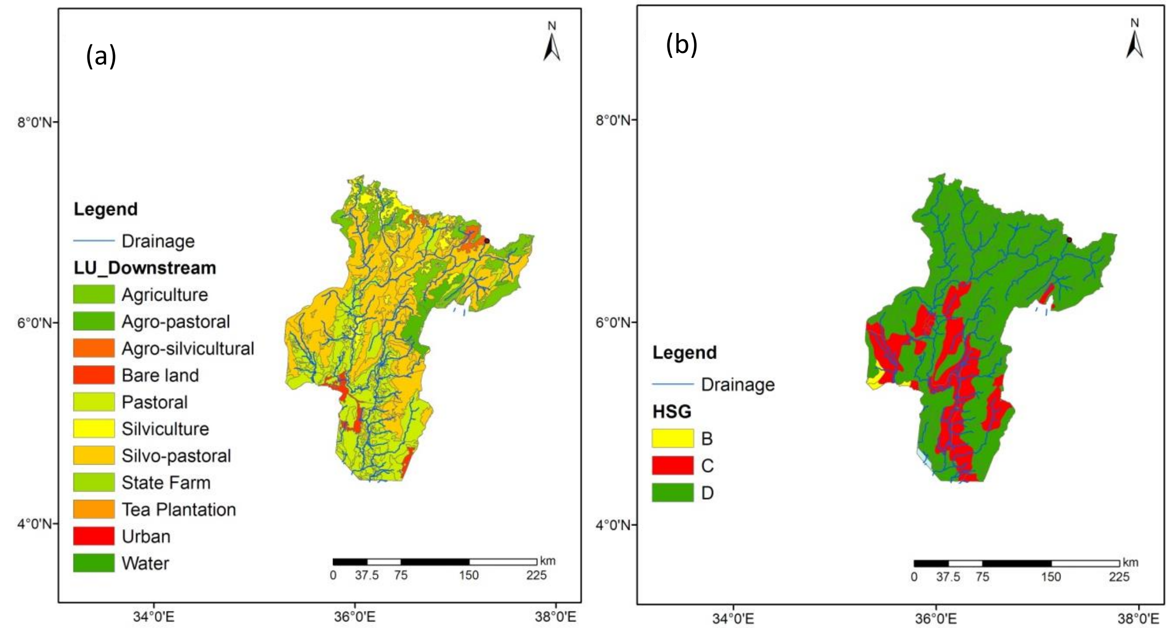

Figure 12: Land use (a) and Hydrologic Soil Group (B) downstream of the Gibe III dam

The dry season evapotranspiration requirement of the potential flood-based farming area is estimated as 25200m3/ha. On the other hand the release from the live storage of Gibe III (considering evaporation loss) is close to 11.0 km^3 and the runoff yield from the catchment downstream of Gibe III based on the runoff coefficient is estimated at 8.19 km^3. There is a difference in the results of the SCS-CN and runoff coefficient method of estimating the annual runoff. According to Teka et al. (2013), the SCS-CN method of estimating annual runoff based on individual events provide a reliable result than the Rational method. But, if an annual based estimations are considered, the Rational method gives reliable result. In general, 8.19 km^3 magnitude of runoff cannot meet the water demand of the potential flood-based farming in the basin. Moreover, according to EEPCo (2009), the recorded natural minimum mean monthly flows is in the month of March (about 25 m^3/s) and as a priority this value has been recommended as absolute minimum monthly average compensation flow which must be sustained the under whole operation of the scheme. As a result, based on the amount of runoff sufficient to meet the flood-based farming, close to 0.75 million ha can be irrigated.

5. CONCLUSIONS AND RECOMMENDATION

Omo River basin is one of the potentials for flood-based farming in Ethiopia. The traditional flood-recession farming is concentrated at only few spots along a strip of the river bank. The potential flood-based command area in the basin is estimated at 1.5 million ha. However, based on the availability of surface water potential and ecological demands downstream, close to 0.75 million ha of land can be covered under flood-based farming at Omo River basin. On the contrary, the maximum river flow (i.e. recoded in 2006) could inundate an area close to 19,000 ha. This indicates that the existing traditional flood-recession farming utilizes a very small portion of the potential that can be irrigated using flood-based farming. The existing traditional recession based farming brought several challenges to the local people. Improving the traditional recession farming becomes important. The challenges related to the traditional recession farming can be resolved through many mechanisms, among which is provision of dams that provides regulated outflow. This regulated outflow reduces the risk of flooding in the lower Omo valley and can be easily utilized for both traditional and modern flood-based farming to meet the ever increasing demand of the local and national agricultural crop production. However, the impact of such development endeavors could be understood well if there is a comprehensive water resource planning study is conducted at a basin level. This study helps to verify the influx needed to sustain Lake Turkana which is reported by Avery (2010).

Although the assessment of the potential flood-based farming conducted in this study is a useful contribution to greater understanding of the potential of the basin, the results do not enable policy formulation on their own. The study on the potential assessment of Flood-based farming system should be evaluated based on some hydrological and water resource modeling. Moreover, crop water requirement for at least the common crop and cropping calendar should be estimated.

6. ACKNOWLEDGEMENT

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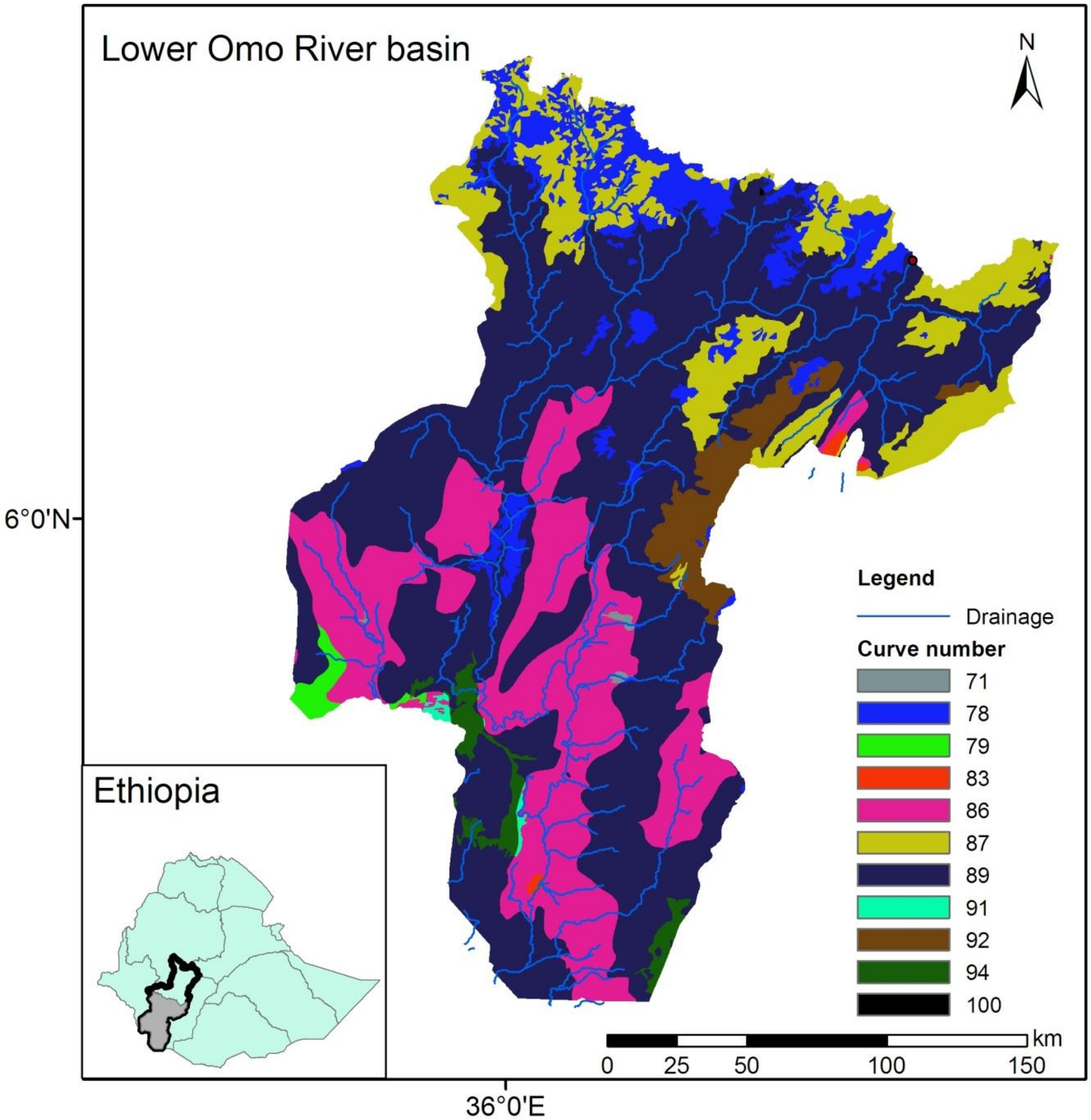
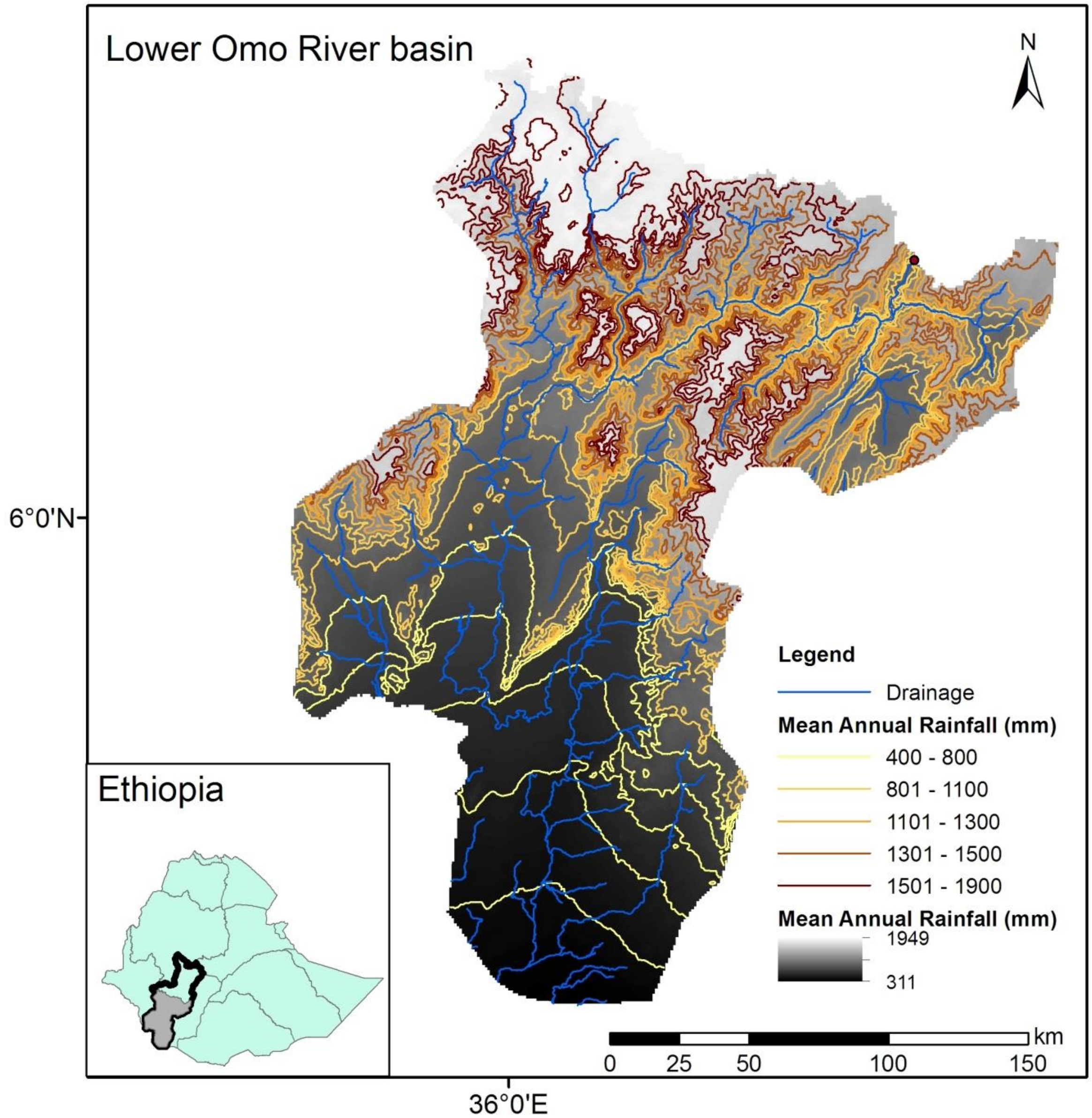
ANNEX

Curve Number Map of the lower part of the Omo Gibe Basin



Annual rainfall Map of the lower part of the Omo Gibe Basin



Potential FBF Assessment using Rational Formula

S. no	Name	Result	Unit	Remark
1	Basin Catch area	74,000	km2	Basin Catchment Area
2	Gibe III catch	34,150	km2	Gibe III Catchment Area
3	Catch: d/s of Gibe III	39,850	km2	Catchment Area D/s of Gibe III
4	Gibe III Live Storage	11.75	km3	Gibe III
5	Dam height	223	m	Gibe III
6	Max surface area	211	km2	Gibe III
7	Average surface area	105.5	km2	Gibe III
8	Annual ETo	2190	mm	Annual Eto
9	Evapo loss	0.23	km3	Evaporation Loss
10	Ecological discharge	25	m3/s	Environmental release
11	Design flow, turbine	950	m3/s	Design flow, turbine
12	Yield of Gibe III	0.79	km3	Environmental release
13	MAR: D/s of Gibe III	1081.35	mm	Mean Annual Rainfall
14	Annual Yield d/s of Gibe III	**8.19**	km3	Annual D/s Yield
15	Total D/s release	19.71	km3	Gibe III Release + D/s Annual Yield

Potential FBF Assessment using SCN CN Method

Average CN	87	
S	38.0	mm
Ia	7.6	mm
Catchment		
Area	39,850,000,000	m2

Month	*RF (mm)*	*Q (SCS_CN) mm*	*Q (SCS_CN) km3*
Oct	23.20	4.55	0.18
Nov	21.40	3.68	0.15
Dec	2.50	0.79	0.03
Jan	0.50	1.63	0.06
Feb	9.90	0.13	0.01
Mar	24.90	5.42	0.22
Apr	65.20	34.73	1.38
May	46.60	19.77	0.79
Jun	10.90	0.27	0.01
Jul	13.60	0.82	0.03
Aug	22.30	4.11	0.16
Sept	14.90	1.18	0.05
Annual	**255.90**	**77.08**	**3.1**

Crop Water Requirement Calculation for Maize

Kc	Stage of Development				Total
Maize	Initial	Crop Development	Mid-season	Late	
Days	30	50	60	40	180
Kc	0.3	0.5	1.2	0.5	0.7
k	0.7		Average Crop Coefficient, Maize		
ETo	8	mm/day	Potential Evapotranspiration		
Growing period (Maize)	180	days			
Etc	1008	mm	Crop Evapotranspiration for Maize		
Overall Efficiency	40 %				
Duty	25200	m3/ha	CWR		

FBF Irrigation Potential Determination

S.no	Scenario I- Considering Releases from Gibe III		
1	Water available	19.71	km3
2	Duty	25200	m3/ha
3	Ecological discharge	0.79	km3
4	Irrigable area	750715	ha
	Scenario II- Without Considering Releases from Gibe III		
5	Water available	8.19	km3
6	Duty	25200	m3/ha
7	Ecological discharge	0.7884	km3
8	Irrigable area	293614	ha