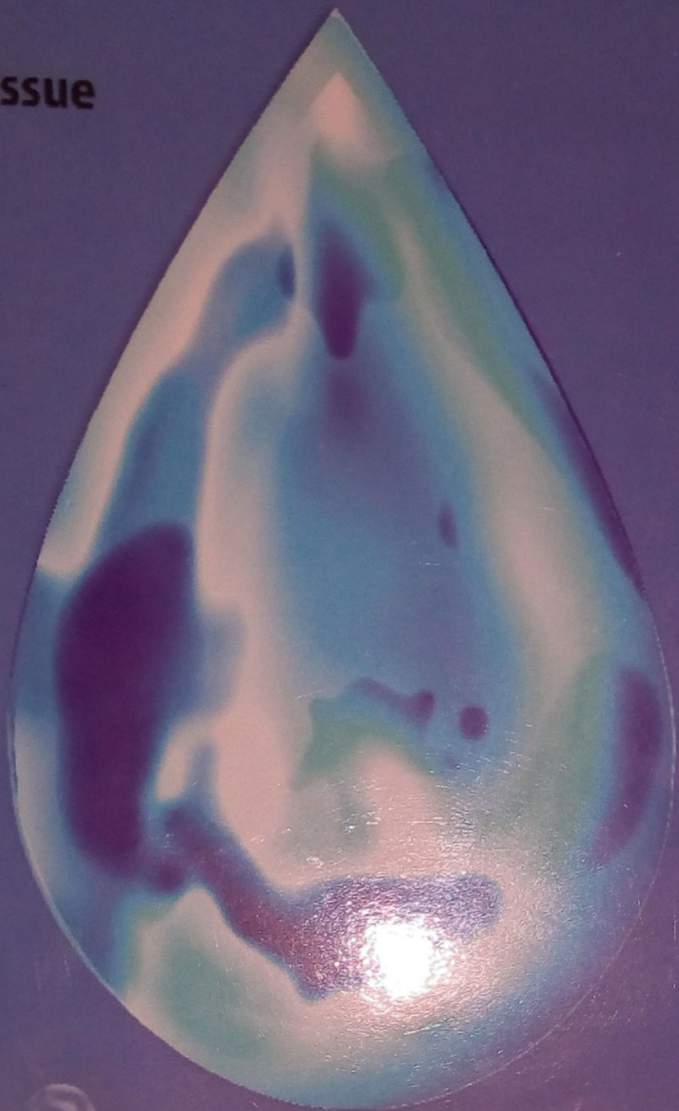
Water

Ethiopian Journal of Water Science and Technology

Special Issue



Proceeding of the 15th symposium on sustainable water resources development
Held at Arbaminch university
from July 3-4/2015
Arba Minch

Water Works Design
and
Supervision Enterprise

Water

Ethiopian Journal of Water Science and Technology

Special Issue

**Proceeding of the 15th Symposium on
Sustainable Water Resources Development
Arba Minch University
from July 3-4, 2015**

Tel.: 0468810453/ 0468814970/ 0916831052

PROCESS OF THE STUDY

Study Methodology

A large number of stakeholders, including many small-scale farmers and pastoralists, were consulted in the course of the study at the kebele, woreda, regional, and federal level. The study has employed standard and scientific methods for gathering data and making analysis. The major data collection methods and tools include extensive document analysis (published and unpublished previous and ongoing study documents), in-depth interviews, resource persons and rapid assessments, focus group discussions, workshops, survey from various regions and city administrations.

Specifically, this study has passed a rigorous multi-step process including:

- **Extensive review of the relevant literature** – the meat industry sub-sector strategic plan preparation has been the subject of extensive investigation. The study team conducted a thorough review of published and unpublished works, national and international strategic documents, and ongoing study documents which provided a starting point for the team's work. Furthermore, an analysis of successful model countries cases provided a context within which to understand the enabling factors in other economies for successful interventions.

- **Collection and analysis of primary qualitative/ quantitative data** – primary data was collected to fill key gaps in the existing data set. This fact-driven analysis allowed the study team to make sectoral projections and modeling around constraints and opportunities in the value chain. These analyses provided the basis for a broad set of systemic recommendations.

    - **Survey** – to generate primary qualitative and quantitative information about the actors in the livestock sector and meat industry sub-sector in Ethiopia, the study team conducted the survey from August 12 to 27, 2014. Specifically, the following activities have been accomplished during the survey period:

        - **Sample area coverage:** The survey area covered seven regional states and two city administrations, namely: Afar, Amahara, Tigray, Oromia, SNNPR, Somali, Hareri, Dire Dawa and Addis Ababa (for details see annex IV from B- C).

- **Sample size:** During this process, a total of 903 respondents from various categories were planned to be interviewed. But practically 650 respondents (from various categories) were interviewed individually and in group (for details, see annex IV from B- F). Moreover, key officials from relevant government institutions (in each respective regions) such as woreda offices of agriculture development, bureau of agriculture and rural development, custom offices, woreda trade and industry offices, regional trade and industry bureau, research institutions and academic institutions, NGOs, municipality abattoirs in each sample region and city administrations, meat processing factories/export abattoirs, livestock breeding improvement ,multiplication and distribution centers were visited and contacted. Besides, reports, plans, research works, collected data were gathered as secondary information to triangulate the primary data.
- **Target population /categories :**the survey attempted to incorporate various target population /categories: Meat animal fatteners , animal fatteners , breed improvement and dissemination center ,animal feeding/forage and other input providers, animal health service center, collectors/live animal traders , live animal market centers and roots (including live animal informal trading corridors), local high meat consumption area, hotels/restaurants, supermarkets, butchers , consumers , abattoirs , meat processing factories , experts , development workers, research institutions and universities , finance institutions , regional , zonal and woreda officials and other relevant stakeholders/actors.
- **Data collection instrument:** comprises structured questionnaire, key informant interview, focus group discussion, rapid assessment, field visiting, picture and audio. Secondary data source using personal request from various identified regional bureaus, zonal and woreda offices, research institutions, universities and others. Moreover, in order to counter check the primary and secondary information collected from the respondents , physical rapid observation of livestock market area, trekked marketable animal, butchers, export abattoirs, livestock breeding improvement ,multiplication and distribution centers , slaughterhouse and fattening farms have been done. Furthermore, relevant pictures were collected and incorporated in the document.

Content	Pages
Foreword (Dr. Mekonen Ayana)	4
Welcome Address (**Dr. Feleke Woldeyes**, President of Arba Minch University)	5-6
Opening Speech (**Professor Henk Ritzema**, Wageningen University, Wageningen, The Netherlands)	7-8
*Impacts of Climate Change on Agricultural Soil and Forest resource and its implication on food/feed security in Ethiopia , A review, 2015.**(Abera Assefa[1] and Habtamu Admasu[2])***	10-21
Water Resource Evaluation and Investigation of its Quality and Sustainability for Irrigational purpose using GIS Technology Reference from Open hand dug wells and River Streams, a case study in Elala catchment, Northern Ethiopia, East Africa. ***(Amanuel Gidey)***	22-26
*Urban Domestic Wastewater Treatment Using Waste Stabilization Pond Technology With The Help of RS and GIS Application, In The Northern Ethiopia, Tigray Regional State, Mekelle City".**(Amare G/Medhin,)***	27-33
Rural water supply and its challenges in developing economies (Review Paper). ***(Beshah M.Behailu)***	34-38
Flood Hazard Mapping, Forecasting and Early Warning development in the Baeo-Akobo-Sobat Basin, Gambella Region of Ethiopia and Sudan Adjacent Regions. ***(Eng. Chuol Biel Thoan[1], Dr. Yosif A. Ibrahim[2], Dr. Alemseged Tamiru[1])***	39-48
Assessment of Urban Water Supply and Sanitation: The Case of Bedesa Town, Damot Woyde Woreda of Wolaita Zone, Southern Ethiopia. **(Ermias Mekonnen[1], Brook Abate[2] and Kannan Narayanan[2])**	49-55
Erosion Hazard Assessment, Case study of Dhidhessa Sub Basin. **(Girma Nigusse)**	56-60
Hydraulic Performance Evaluation of Hare Community Managed Irrigation Scheme, Southern Ethiopia. ***(Mamuye Tebeba[1] and Mekonen Ayana (PhD) [2])***	61-68
The Effect of Soil Erosion on Reservoirs Life Expectancy A case study on Belbela reservoir, Ethiopia. ***(Mastewal Tesfaye[1], Prof. Dr. Charlotte De. Fraiture[2], Dr. Laszlo G. Hayde[2], Dr. Shreedhar Mskey[2])***	69-77
Seasonal Stream flow Variability Analysis and Forecasting, Lake Tana Sub-Basin, Upper Blue Nile Basin, Ethiopia.**(Mengistu A. Jemberie[1], Adane A.Hawas[2])**	78-86
Wastewater Management in Wet Coffee Processing Mills and their Impact on the Water Quality Status of Gidabo River and its Tributaries, Southern Ethiopia. ***(Mihret Dananto Ulsido[1*], Meng Li[1])***	87-97
The Role of the Grand Ethiopian Renaissance Dam (GERD) Beyond Generating Hydroelectric Power: Appraising Its Potential Contributions for the Development Water Based Tourism in Ethiopia. ***(Mohammed Jemal Ahmed)***	98-103
Analysis of Hydro Climatic Trends in Guder Sub-basin: Blue Nile River Basin, Ethiopia.**([1]Mosisa Tujuba, [2]Abraham W/Michael, [3]Tena Alamirew)**	104-109
*The 2015 Khartoum Agreement: Is Ethiopia's Diplomatic successes or Egypt's change in Policy over The Nile?**(Seid Ahmed)***	110-115
Assessment of Drinking Water Quality in Mercato, Addis Ababa. **(selamawit Mulugeta)**	116-120

Foreword

Ethiopia has huge physical water resources potential. However, due to different constraints, its contribution to socio-economic development of the country has been low. Since few years the country is aggressively designing and implementing many programs and projects that are used to harness, develop and utilize the water resources for the national development purposes. While developing and utilizing the resources, issues of sustainable development and management of these resources requires attention. Arba Minch University organizes symposia on Sustainable Water Resources Development since the last twelve years.

The objective of the symposium is to create a platform where professionals, researchers, practitioners and decision-makers come together and share ideas, communicate research results, good practices and innovations in that can enhance sustainable water resources development. This year the symposium marks the 15th cycle in the series. The organizing committee has received more than 60 papers in different thematic areas announced in call for papers. After review process, about 28 pares have been selected for oral presentation and 10 papers for poster presentation.

This proceeding contains the full contents of presented papers. I believe the research results presented in these papers can be useful references for the readers. On behalf of the organizing committee and myself I thank all contributors to this Symposium.

Mekonen Ayana, Ph.D
Director, Water Resources Research Center
Editor

Acknowledgement

The contributions of Water Works Design and Supervision Enterprise, South Design and Construction Supervision and Germen Agro Action-Welt Hunger Hilfe are highly appreciated.

Welcome Address

Dr. Feleke Woldeyes, President of Arba Minch University

Your Excellency (**Professor Henk Ritzema**, Wageningen University, Wageningen, The Netherlands)
Distinguished guests,
Ladies and Gentlemen:

First and for most, I say you all welcome to this **15th Symposium on "Sustainable Water Resources Development"** which AMU is hosting.

Water is one of the most important resources on earth; and it is the most essential element to human life- next to air (oxygen). We all know that the living cell is largely composed of water (≥75 %); and the universal solvent is essential to the functioning of every single cell and organ system in an organism's body. Moreover, as scientific theory holds, life itself emerged in the ocean. Besides its use for routine household uses such as drinking, washing, cleaning; water has always fascinated Man. The first civilizations of man started near rivers, and the vast expanse of seas and oceans has long been our major sources of food and means of travel.

Though water covers about two thirds of the total surface of the earth, there are various problems connected with the abundance of water and which, of course, are far from being resolved. All over the world, water is getting sparser and some countries are continuously looking for new sources of drinking water. The industry requires a large amount of water for the manufacturing processes, as so does agriculture. The rapidly increasing human population needs water for domestic purposes and to generate energy.

According to sources, agriculture alone consumes 70% of our fresh water resources while industry and power generation use some 22%. Nevertheless, only about 8% is used for human consumption and in human health. Some 1.5 billion people do not have access to wholesome water; some 50% of the world's population does not have adequate water purification systems; and more than 30 million people die every year from diseases linked to polluted water (cholera, malaria, hepatitis). Ethiopia is among those countries that are endowed with very rich water resources but not utilized the resource efficiently both in the agricultural and industrial sector. We also know that clean water supply to households at a very low level.

This all reminds us that there is a need to vigorously work in the area so as to develop the water sector. Occasions like the present gathering which gives scholars opportunity to come together and share ideas and conduct academic discussion is believed to contribute towards that end. I therefore believe that we will gain a lot from each other and generate ideas the will help in better utilization of the water resources of the country.

This symposium has become a reality due to the relentless effort made by many and I am particularly thankful to the organizing committee.

I would also like to extend my sincere appreciation to paper presenters and participants who showed interest to participate in the symposium and travelled hundreds of kilometers to join us here. In addition, let me take this opportunity to express my gratitude to the International Water Management Institute, University Partnership, and Horn Africa Regional Environmental Center and Network for co-organizing the symposium.

Wishing you all to have a pleasant time during your stay here in Arab Minch, I once again say welcome to Arba Minch and AMU.

Thank You

Opening speech

Dear Workshop Participants
Ladies and Gentlemen,

First and foremost it gives me great pleasure to welcome you all to this 15th Symposium on Sustainable Water Resources Development.

Water is an indispensable natural resource upon which all lives depend on. Hence water security is crucial to sustain life. When we say water security, we are referring to a situation of reliable and secure access to water over time. Some regions are characterized by abundant physical water resources whereas others are suffering from water scarcity. Capacity to harness the available water resources so as to ensure its availability and accessibility in the required quantity and quality is also different from country to country.

With increasing population and improved living standards the demand for good quality water also increases. However, water scarcity is threatening many regions of the world and hence more than 1.2billion people in the world lack access to this important resource.

With regards to water availability, literature makes distinctions between physical, economical and technical water scarcity. Although Ethiopia is considered as a country with vast water resources potential, the availability and accessibility of water both in terms of quantity and quality to different uses has been limited. This was mainly accounted to lack of the required technical and financial capacities and capabilities to harness our water bresources potential. Hence, as per the definitions of literature, Ethiopia has been belonging to one of those regions suffering from economical and technical water scarcity.
Generally, the term water scarcity describes the relationship between demand for water and its availability. Not only the availability but also the demands may vary considerably between different regions within a given country, depending on the sectoral usage of water. Agricultural sector has been considered as the dominant user of freshwater. However, with the development of industries and urbanization, demand for water is also increasing from industrial and domestic uses. Sustenance of ecosystem functions also requires water of specific quality and quantity. With increasing population growth and demand for food production the water demand will increase. Therefore, efficient allocation of water among different uses including ecosystem is required.

The freshwater cycle in Ethiopia is governed by 12 major river basins with annual runoff potential of 123 BCM. These rivers are feed by heavy winter rainfalls over Ethiopian highlands which makes most often concentration times of flows short. As a result high water availability periods or peak runoff times are concentrated to only 3 to 4 months of the year. This uneven distribution of water makes water storage crucial to ensure sustain economic growth and eradicate poverty. Our water storage facility per capacity is among the least in the world which requires attention.

Following the results of river basin master plan studies, we are progressing to implement water resources development projects in many of our river basins. In the course of project identification, feasibility studies, design, construction and operation of our water resources projects, we follow international standard procedures of social and environmental impact assessments. As these projects are created with huge investments, sustaining their positive impacts requires minimizing possible negative social and environmental impacts.

With increasing population our watersheds are increasingly threatened by poor land use systems such as deforestation, overgrazing, over-cultivation and so on. With this regards, the consequences of land degradation and soil erosion on water resources development infrastructure is becoming priority concern. Silting-up of water storage structures like dams and reservoirs as well as irrigation canals are major problems we are facing. Parallel to investments in development of new projects, due emphasis should be given to integrated watershed management. Many soil and water conservation efforts are underway in different regional states of our country. These interventions need to be supported by scientific knowledge to sustain their positive impacts.

Climate change and variability is another emerging issue that deserves attention. The Sub Saharan part of Africa in general has been affected by major drought and flood events over the last Century. The adverse effect of such climate variability has significantly been observed on agriculture, water supply and hydropower sectors in Ethiopia. In order to minimize the negative consequences of ensuing climate variability, introduction of appropriate climate change adaptive mechanisms at different levels and development of climate resilient green economy is vital.

Our water resources development and management endeavors need to be supported by scientific researches. However, research capacities and experiences in water resources are still at infant stage. The existence and availability of water is affected by the interaction of many environmental and socio-economic factors. Its transboundary nature connects different nations and nationalities with different levels of economic development, cultures and values. Research is important to generate information and knowledge related to the likely change in demand and supply of water in different time horizons, socio-economic and environmental impacts of intervention, adoption and adaptation of appropriate technologies to enhance efficient use of water and so on.

To contribute to the research capacity building, Arba Minch University has completed the necessary preparation to launch PhD program in Water resources engineering. The first batch of PhD candidates will be admitted as of the beginning of the next academic year.

I am informed that several research papers addressing various areas of water resources are selected and ready for oral and poster presentation. This platform will definitely create opportunity for you to share experiences, exchange ideas, disseminate your results and learn from each other.

Ladies and Gentlemen,

Finally, I would like to thank the financial contribution of Water Works Design and Supervision Enterprise, South Design and Construction Supervision and Germen Agro Action-Welt Hunger Hilfe. I thank also the organizing committee of this symposium who has worked hard to realize this.

I wish you fruitful deliberations during these two days and declare that the symposium is officially opened.

Thank You.

Impacts of Climate Change on Agricultural Soil and Forest resource and its implication on food/feed security in Ethiopia

A review, 2015

Abera Assefa[1] and Habtamu Admasu[2]

[1,2] Ethiopian Institute of Agricultural research, Melkassa Agricultural research center, P.O. Box 2003 Adama

aberaassefa@gmail.com and habtamu.admassu@gmail.com

Abstract

This paper document existing literature regarding the past, current and projected impacts of climate change on agricultural soils of the Ethiopia. We consider past and expected change within the context of recently observed climate variability in the country to better understand the potential impact of expected change. Available literature showed that extreme weather and greater climate variability due to climate change is expected to become more common in the future and its impacts on soils and agricultural production and food security. Reviewed literature also climate change will have both but negligible positive and more negative impacts on the natural resources characteristics and systems. The impacts of climate change in Ethiopia will have profound agricultural production making the sector and the people who depend on it most vulnerable to climate change. Since, 80% of populations of the country depend on natural resources for agriculture it is important to develop strategies to safeguard natural resources in a changing climate. Ethiopian agriculture must adapt and register a major breakthrough through better management of natural resources so that it can feed the ever increasing population as climate change unfolds. To adapt to the multiple challenges of climate change, and achieve the goals of food/feed security, overcome malnutrition, make poverty things of the past, the country must create a climate smart landscape in order to exploit the advantage of climate-smart agricultural practices. Fundamental to realize accelerated agricultural transformation and to achieve a vision of Zero hunger Ethiopia on sustainable basis requires serious policy commitment. Thus, we recommend an integrated participatory action orientated approach to management of the natural resources at watershed scale to create climate smart land escape and mainstream climate-smart agricultural adaptation technologies and mitigation strategies by mobilizing farmers, researchers, trading communities, political decision makers and NGOs.

Introduction

Agriculture accounts for over 40 percent of GDP and 80 percent of exports, and engages 80 percent of the labor force in Ethiopia. The country has vast areas of fertile land, a diverse climate, generally adequate rainfall, and a large labor pool. Around 75 percent of Ethiopia's approximately 85 million people are dependent on subsistence agriculture, which is almost entirely rain fed and small scale. Both farmers and pastoralists are highly dependent on the weather and natural resources for their livelihoods (Lukac *et al.*, 2010). Some of natural resources such as water, soil and forests are environmental goods that provide many other goods and services (media, wood, food, feed, aesthetic value, etc) to human being and natural systems are susceptible to the adverse effects of climate change (NMAE, 2007; Pimentel, 2006; and Brevik, 2013).

According to (IPCC, 2007) Climate" refers to atmospheric conditions that have timescales that range from a few months to a season to a year to a decade or more, or even longer. Climate change is a long-term continuous change in a climate normal (for example, an increase in the long-term average temperature) and/or the range of climate variability of its properties (IPCC, 2007).

According to Bathke *et al.*; (2014), a climate change *impact* means: A specific change in a system caused by exposure to climate change. Climate change has already altered, and will continue to alter the soil process and properties and forest resource composition and growth for all uses (Brevik, 2013; Jennie *et al.*, 2010).

Therefore, there is evidence on climate change adverse impacts on land resources and socio-economic development of Ethiopia. IPCC findings indicate that developing countries such as Ethiopia which has a fragile highland ecosystem that is currently under stress due to still increasing population pressure will be more vulnerable to climate change (Boko, 2007). Rising temperatures and increasing climate variability is already imposing a significant challenge to Ethiopia by affecting food security, water and energy supply, poverty reduction and sustainable development efforts (Jennie *et al.*, 2010; IPCC, 2007). It also exacerbates natural resource degradation and natural disasters (NMAE, 2007).

Changes in the earth's climate has been hit developing countries like Ethiopia, because their economies are strongly dependent on crude forms of natural resources and the economy of the country mainly depends on agri-culture that largely depends on available water resources while a large part (60%) of the country is arid and semi-arid (Boko, 2007).These challenges may be amplified by extreme events having social and economic impacts. In the fact of that, regions with an arid and semi-arid climate could be sensitive to even insignificant changes in climatic characteristics. Overall, Climate change has positive and negative effect on the land resources and affects food se-curity (Pimentel, 2006; Brevik, 2013; and Brevik, 2012). The socio-economic processes that drive land-use change include population growth, economic development, trade and migration; these processes are integrated with climate change negatively affected natural resources and treat livelihood (Boko, 2007).

We review current knowledge on the impacts of climate change on land resources (soil, water and forest) to high-light priority targets for new research and to summarize the observed and projected impacts that enable the flow of information between stakeholder groups with an interest in natural resource conservation in a changing climate. Even though, we have in general constrained our discussion to information from Ethiopia, we include infor-mation from some studies outside of Ethiopia or at the global scale in order to illustrate some generic climate change impacts. This information is not intended as a comprehensive review of climate change impacts on Ethi-opian land resources, but instead is meant to illustrate some of its major features.

Trends of Climate Change

The intergovernmental panel on climate change (IPCC) fifth assessment report (AR5) confirmed with 95-100% certainty that climate change is the result of human activi-ty, emission of greenhouse gases (GHG) (e.g. CO_2, CH4, and N2O, etc.) from burning fossil fuel, deforestation and land use change. Concentrations of greenhouse gases (GHGs) are now at new highs, with carbon dioxide (CO_2) at 377.1 ppm, methane (CH4) at 1783 ppb and nitrous oxide (N2O) at 318.6 ppb. The global mean carbon diox-ide concentration CO_2 increased from 280 to 392.6ppm an average warming of approximately 0.8°C, with an in-crease of 0.6°C in the past three decades in the period 1750-2012 (Boko, 2007; IPCC, 2013). CO_2 is the most abundant GHG, which accounts for more than 75 % of the total GHG emissions annually and causing the atmosphere to trap more heat, which results in global warming (IPCC, 2013). Although rainfall patterns and seasonal temperature are common in climate expressions, the average surface temperature is a key global climate variable (USGCRP, 2009). Unpredictable flood and drought is an indicator and posed by Climate change.

In the past three decades Global Mean Surface Tempera-ture (GMST) has been warmer than all the previous dec-ades (IPCC, 2013). Globally, there will be average tem-perature increase of 2°C by 2100 (Sokolov *et al*; 2009). The minimum temperatures over Ethiopia show an in-crease of about 0.37◦C per decade, which indicates the signal of warming over the period of the analysis 1951-2005 (NMA, 2007).Similarly, IPCC (2012) predictions shown us, global temperatures will increase by 1 to 3 °C by the mid-21st century and by about 2 to 5 °C by the late 21st century. Ethiopia as a part of the Horn of Africa be-coming hotter and hotter as the mean annual temperature is projected to increase by 1.1 to 3.1°C by 2060s, and 1.5 to 5.1°C by 2090s (Raleigh and Kniveton, 2012). During the past 100 years, the Earth's climate has experienced, and the 1990s being the warmest decade in the observa-tional record (IPCC, 2001).

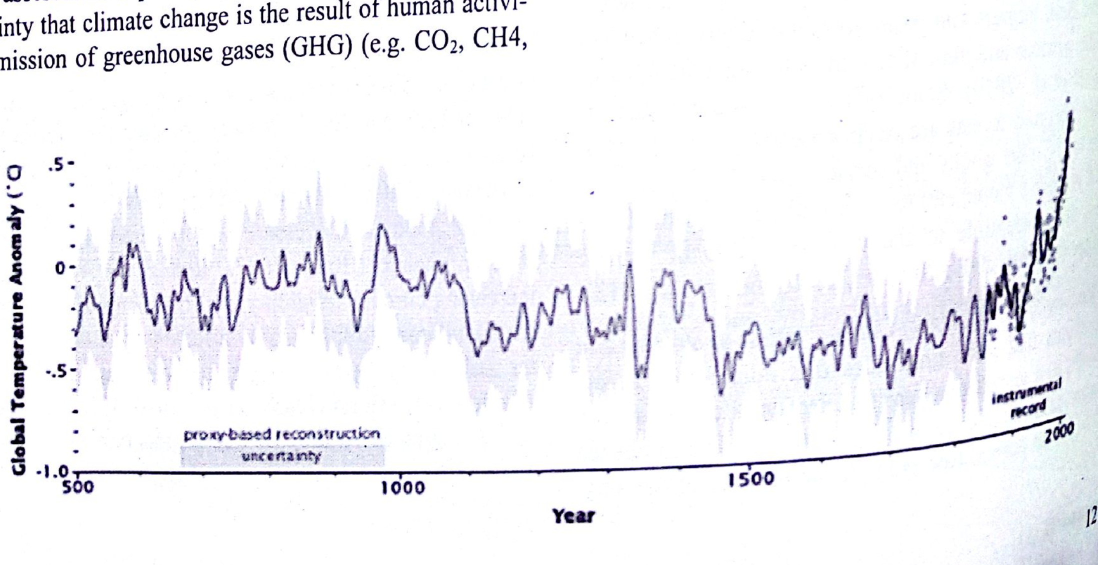


Figure 1: Reconstructed global temperature record for the last 2,000 years (Source: Bathke *et al;* 2014)

Temperature effects are often better understood than others climate parameters. However, precipitation has much larger spatial and temporal variability than temperature, and it is therefore more difficult to identify the impact it has on changes in many systems (IPCC, 2001). Williams and Funk (2011) explained about a reduction in the long rains over Kenya and Ethiopia in response to warmer Indian Ocean sea surface temperatures (SSTs). It is very likely that the numbers of warm days and nights have increased globally since 1950 (IPCC, 2013) with limited data on African heat waves. The frequency of heavy precipitation is likely to increase, even in areas where total annual rainfall is expected to decrease that will affect livelihoods of people especially developing countries in Africa (IPCC, 2012).

There is considerable interannual variability, but rainfall increases from about 1000 mm/y near the border to between 1400 and 1800 mm/y over parts of the upper basin and exceeds 2000

mm/y in some places in the south (Awulachew *et al.*, 2008). The summer months account for a large proportion of mean annual rainfall; averaged across the basin, approximately 70% occurs between June and September. Potential evapotranspiration also varies considerably and, like rainfall, is highly correlated with altitude. In the highlands of Ethiopia, potential evapotranspiration ranges from approximately 1300 to 1700 mm/y and in many places is less than rainfall in the rainy season. Consequently, rainfed cultivation, producing a single crop in the rainy season, is possible – though risky in low-rainfall years (Awulachew *et al.* 2008).

The overall coefficient of variability in rainfall of the country ranges from 10-50%. The arid and semi-arid regions which constitute 60% of the country's surface area experience a coefficient of variation of 50% whereas the rainfall fluctuation in the South-Western regions is usually less than 20% (the coefficient of variation is simply the standard deviation divided by the average annual rainfall (Workineh, 1987).

Table 2. Observed climate change over the twentieth century, comparing means for 1900–50 with means for 1950–2000.

African basins	Limpopo	Niger	Nile	Volta
Precipitation, mm/month (mm/yr)	−1.2 (− 13.8)	−1.3 (− 15.9)	−0.4 (− 4.8)	−0.3 (− 3.4)
Temperature, °C	0.1	−0.9	−0.6	−0.4

While there is generally no significant change detected in the annual rainfall in most of the Nile sub-basins, there appears to be decreasing seasonality in some key watersheds of the upper Nile in Ethiopia such as the southern Blue Nile and Baro Akobo

In addition, climate change is projected within near future to reduce yields of the wheat staple crop in Ethiopia by 33% (NMAE, 2007).However, the IPCC report suggests that it is not too late to prevent the worst impacts of climate change, if countries of the world act now (IPCC, 2013). These include consideration of factors such as future economic performance and population patterns. Therefore there is a need to carry out climate change research and studies to better understand impacts of current climate variability particularly on hydrology.

Climate change threats on natural resources

Annual losses to the Ethiopian economy could be up to, 46% of GDP, due to the impact that climate change will have on its natural resources alone (MoWE, 2001). Over the coming decades, the valuable natural resources and ecosystem services on which people depend will be increasingly affected by warming temperatures, rising seas, and more frequent and severe drought, among other expected climatic changes (Legates *et al.*, 2005). In some cases, major, rapid disruptions to ecosystems may occur when ecological thresholds are crossed due to climate change in combination with other stressors (Awulachew *et al.*, 2008; Bowden *et al.*, 2009; Conway & Hulme, 1993).

Impact of Climate Change on Soil

Since soils are integral parts of several global nutrient cycles it is linked to the climate system through the carbon, nitrogen, and hydrologic cycles. It is important to know that, climate change interactions are the carbon and nitrogen cycles because C and N are important components of soil organic matter (Brady, 2008)and carbon dioxide (C_2O), and nitrous oxide (N_2O) are the most important of the long-lived greenhouse gases (Hansen *et al;* 2007).

CC has positive and negative effects on the environment, including the soil (Brevik, 2012). Soils are also important to food security and climate change has the potential to threaten food security through its effects on soil properties and processes (Pimentel, 2006; Brevik, 2013). The largest active terrestrial C pool is in soil, which contains an estimated 2,500 Pg of C compared to 620 Pg of C in terrestrial biota and detritus and 780 Pg of C in the atmosphere (Lal, 2010).

Soils naturally sequester C through the soil-plant system as plants photosynthesize and then add dead tissues to the soil (Lal, 1998; Bervik and Honburg, 2004). Carbon is also naturally emitted from soils as CO_2, and methane CH_4 gases due to microbial respiration, with the form of the C gas depending on the oxygen status of the soil system.

Human management of soils can have a profound impact on the balance of C and N gas emissions from those soils, and therefore influences global climate change (Brevik, 2012). The C and N cycles are key parts of the global climate system, and soils are an integral part of these cycles. Climate change, in turn, is expected to influence soil erosion and food security. Therefore, there is an interaction between soils and the atmosphere in a changing climate and it has a potential influences on food security through the erosion cycle.

Influence of Climate Change on Soil Properties and Processes

Climate change has effects on soil processes and properties through causing potential changes in the C and N cycles that will influence soils (Brevik, 2012). Carbon and nitrogen are major components of soil organic matter. Organic matter is important for many soil properties, including structure formation and maintenance, water holding capacity, cation exchange capacity, and for the supply of nutrients to the soil ecosystem (Brady, 2008).

The increased atmospheric CO_2has CO_2 fertilization effect and would lead to increased plant productivity coupled with increased C sequestration by soil, meaning increased plant growth and the soil-plant system would help offset increasing atmospheric CO_2 levels (Coughenour and Chen 1997). However, recent studies indicate the CO_2 fertilization effect may not be as large as originally thought (Poorter and Navas 2003; Zaehle *et al;* 2010).

A long-term elevated CO_2 experiment in a grasslands ecosystem indicated that N and P became limiting within two years, again limiting plant biomass response to elevated CO_2 (Niklaus and Körner, 2004). Therefore it can be concluded that the increases in plant productivity they did see were due primarily to soil moisture status as opposed to a CO_2 fertilization effect. Experiments looking at the decomposition of plant tissues grown under elevated atmospheric CO_2 also indicate that increased levels of CO_2 are emitted during that decomposition (Kirkham, 2011) and research by Carney *et al*; (2007) observed soil organic C levels declining under increased atmospheric CO_2 levels due to increased microbial activity. Therefore, elevated CO_2 levels will not necessarily lead to increased soil C sequestration, but may instead result in more C turnover r (Eglin *et al;* 2011). --

Increasing levels of ozone as the climate changes may actually counteract the CO_2 fertilization effect leading to reduced plant growth under elevated CO_2 (Long, 2005) and the negative effects of increased temperatures on plant growth may also cancel out any CO_2fertilization effect that does take place (Jarvis; 2010). Nitrogen limitations may negatively affect plant growth (Hungate, 2003), and modeling of C dynamics as influenced by N indicates less C sequestration by soil than originally expected given CO_2 fertilization (Zaehle *et al;* 2010).

Increased temperature is likely to have a negative effect on C allocation to the soil, leading to reductions in soil organic C and creating a positive-feedback in the global C cycle (increased temperatures lead to increased CO_2 release from soils to the atmosphere, which leads to more increases in temperature) as global temperatures rise (Gorissen *et al;* 2004; Wan, 2011). In a study of soils in a semi-arid steppe, Link *et al*. 2003 observed that soil warming and drying led to a 32% reduction in soil C over a five year time period, a much more rapid reduction in soil C than reductions that have been observed due to increased tillage. Modeling of C responses to climate change predicted small increases in aboveground biomass in forest and but larger decreases in soil, for an overall increase in atmospheric C (Price, *et al;* 1999). Another modeling study predicted decreases in soil organic C of 2.0%–11.5% in the by 2100 as compared to 1990 C values (Price, *et al;* 1999).

Niklinska, *et al* (1999) measured humus respiration rates under increased temperatures in samples and concluded that the ecosystems studied would switch from net sinks to net sources of samples and concluded that the ecosystems studied would switch from net sinks to net sources of atmospheric C with global warming. It is important to keep in mind that in all these cases, the soil would only be a net source of C to the atmosphere until a new equilibrium was reached. CO_2 enrichment increases the soil C:N ratio and leads decomposing organisms in the soil need more N, which can reduce N mineralization leads to plant productivity reduction (Hungate, *et al*; 2003; Gill, *et al*; 2002; Reich, 2006). Mineralization is an essential step in supplying N to plants (Mullen, 2011). Increasing temperatures increase N mineralization (Norby, 2004), which could have a positive effect on plant growth.

Climate change and anthropogenic activities have also affect soil to become susceptible erosion. As previously established, climate change is expected to increase soil erosion. The negative effects of soil erosion on crop yields and food production are well established. There is a chance to have strong correlations between climate change with soil erosion and negative impacts on aggregate stability, bulk density, water holding capacity, pH, organic matter content, total N, and soluble P in the soil, all properties important for good crop growth and productivity (Brevik, 2009).

There were at least 1 billion people living in a state of food insecurity in 2010; eliminating this insecurity and feeding the additional 2.3 billion people expected by 2050 will require global cereal production, for example, to be increased by 70% (St Clair, 2010). The IPCC expects that climate change will impact all four dimensions of food security, (1) food availability, (2) stability of food supplies, (3) access to food, and (4) food utilization (Easterling *et al;* 2007). Low soil fertility is currently a food security problem in many developing countries. CC integrated with proper soil management has the potential to drastically reduce food. As adaptation option increasing soil organic C in degraded soils would be a major step forward in enhancing food security in developing countries.

Global warming can accelerate decomposition of soil organic matter and enhance C emission from soil causing soil degradation. Therefore, this treat could potentially thwart soil C sequestration efforts and have a negative impact on food security. If C sequestration practices are not started, these already degraded soils are even more vulnerable to the effects of climate change than relatively healthier soils in developed countries (Tan *et al;* 2010). Therefore, climate change has the potential to exacerbate food security issues through its potential effects on soil health. Healthy soils are important because they supply nutrients to the crops grown in those soils. However, if the nutrient is not present in the soil, or if it is not plant available due to being tied up in the soil or through antagonistic affects from other ions, plants cannot access the nutrient and pass it up the food chain. Unhealthy soils tend to have a lower overall nutrient status. Low nutrient status in agricultural soils not only reduces the amount of food available for human consumption, it also makes the resulting crops less nutrient-rich which makes those who rely on the low nutrient soils for crop production more susceptible to disease (Sanchez, 2005). If problems from vector-borne diseases, for example, become more pronounced with changes in climate (Brevik, 2013), low-nutrient status soils will simply make those who rely on them even more prone to experience disease problems (Perez, *et al*., 2007).

Climate change threats forest

Temperature is known to strongly influence the distribution and abundance patterns of both plants and animals, due to the physiological constraints of each species (Parmesan and Yohe, 2003; Thomas *et al.*, 2004).Different plants react differently to the concentration of carbon dioxide CO_2 in photosynthetic CO_2 fixation (Cerling *et al.,* 1993). C_3plants including barley, ice, wheat, soybeans, cassava, potatoes, legumes and most trees grow in cool climates. C_4 plants including maize,s orghum, sugarcane, tef, etc. grow in subtropics (Hatch, 1987). The increase in CO_2 has higher effects in the assimilation of CO_2 in C_3 plants than C_4 plants. In C_3 plants, the assimilation of solar energy into carbohydrates generally increases with CO_2 and decreases with temperature. Doubling CO_2increases photosynthetic rate of C_3 plants by 25–75% (Urban, 2003), therefore, CO_2 has "fertilizer" effect (Ehleringer and Björkman, 1977). Generally, increase in CO_2 reduces the opening of stomata which reduces transpiration of trees, increases water use efficiency, increases plant growth and increases nutrient availability (Sievänen *et al.,* 2013). However, more CO_2 increases warming and limits water availability that could affect plant physiological processes and cause mortality (Reddy and Hodges, 2000).

Species adapts to climate change through insitu physiological alteration or migration (latitudinal and altitudinal spatial shift); and temporal shift (phonological event). The ability of a species to migrate will depend on its capacity to disperse and on the connectivity of suitable habitat (Thomas *et al.,* 2004). Climate change is able to decrease genetic diversity of populations due to directional selection and rapid migration (Botkin *et al.,* 2007).

As the temperature increases warm mixed forests replace cold and temperate forests (EPI, 2012). The failure to adapt climate change results in loss of biodiversity and extinction of species (MEA, 2005).

In Ethiopia climate change affected many aspects of forest ecosystems. For example, the devastation of *Cupressus lusitanica* has been attributed to a combination of recurrent drought. A modeling study predicted that the areas of suitable climate for over 80%of African plant species would decrease in size and shift to higher altitudes. The current habitats of 25–41% of African plant species would be entirely lost by the year2085 (Lovett *et al.*, 2005).

CC has an impact on season of growth (phenology) of the plants in drought time maturity of fruits could delay and no seeding could take place. This phonological shift leads to insect pollinated flowering plants causes mismatches with the metamorphosis of insects that lead to the extinctions of plants.

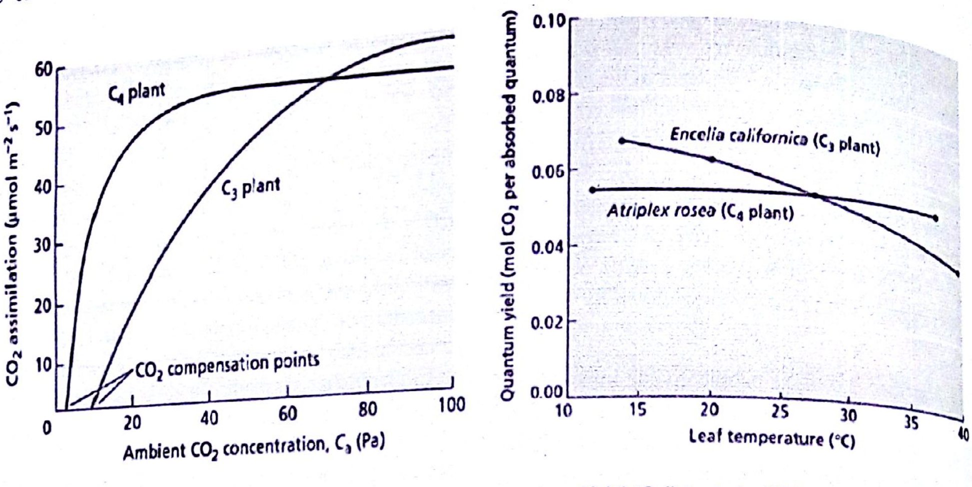


Figure 1. Responses of C_3 and C_4 plants for [CO2] (left) and temperature (right) (Collatz et al., 1992).

Impact of climate change on forest products, species composition and distribution

Some of non-timber forest products (NTFP) have been negatively affected due to climate changes. Increased evaporation that causes moisture stress and reduce yields of NTFP such as gum arabic decline by 25% every 30 years (IUFRO, 2010). Tree species vary in climate change resilience and their productivity. Hardwoods are more susceptible to drought than soft woods species (Pérez *et al.*, 2007). Sohngen *et al*, (2001) projected that the global timber price is increasing year after year. Therefore, it seems that climate change affects the welfare of both consumers and producers.

Climate Change has also great impacts on tree species composition and distribution. Species adapts to climate change through in situ physiological alteration or migration (latitudinal and altitudinal spatial shift); and temporal shift (phonological event). The ability of a species to migrate will depend on its capacity to disperse and on the connectivity of suitable habitat (Thomas *et al.*, 2004). Climate change is able to decrease genetic diversity of populations due to directional selection and rapid migration (Botkin *et al.*, 2007). As the temperature increases warm mixed forests replace cold and temperate forests (EPI, 2012). The failure to adapt climate change results in loss of biodiversity and extinction of species (MEA, 2005).

In Africa climate change affected many aspects of forest ecosystems. In Burkina Faso, for example, the local extinction of several species (e.g. *Adansonia digitata*, and *Anogeissus leiocarpa*) and in Ethiopia, the devastation of *Cupressus lusitanica* has been attributed to a combination of recurrent drought. A modeling study predicted that the areas of suitable climate for over 80% of African plant species would decrease in size and shift to higher altitudes. The current habitats of 25–41% of African plant species would be entirely lost by the year 2085 (Lovett *et al.*, 2005).

Food insecurity: the role of climate variability and change

Rainfall variability and increasing temperature due to climate change is severely impacting on production and productivity of agriculture, the general economy and the livelihood of rural people of Africa. Resilience refers to the ability of a system, community or society to resist, absorb, cope with, and recover from the effects of hazards, and to adapt to longer term changes in a timely and efficient manner without undermining food security or well-being. Resilience is an outcome which can take on different forms. Resilient outcomes include: the ability to manage risks and reduce the occurrence of hazards; to adapt to change over the long term; to secure sufficient food and to move out of poverty trap. It offers the opportunities for increased productivity and food security, enhanced resilience and reduced carbon emissions thereby contributing to sustainable development

Climate variability and change have an impact on food production (Mendelsohn *et al.*, 2000; Kurukulasuriya and Rosenthal, 2003). Broadly speaking, food security is less seen in terms of sufficient global and national agricultural food production, and more in terms of livelihoods that are sufficient to provide enough food for individuals and households (Devereux and Maxwell, 2001). The key recognition in this shifting focus is that there are multiple factors, at all scales, that impact on an individual or household's ability to access sufficient food: these include household income, human health, government policy, conflict, globalisation, market failures, as well as environmental issues (Devereux and Maxwell, 2001). Climate change mainly affects the availability of food from principal components of food security in Agricultural system. For the country, the agriculture sector, which is highly dependent on precipitation, is estimated to account for approximately 60% of total employment, indicating its crucial role in livelihoods and food security derived through food access through purchase (Slingo *et al.*, 2005).

Through many ways of implication climate change has impact on livelihood and food access such as via tourism sector, market access, natural resource and agricultural inputs. Impact of climate variability and change on food security therefore cannot be considered independently of the broader issue of human security (O'Brien, 2006). The resource-poor farmers and communities use a variety of coping and adaptive mechanisms to ensure food security and sustainable livelihoods in the face of climate change and variability. While exploring the local-level dynamics of people's vulnerability to climate change, of which adaptive capacity is a key component, it is important to find ways to embed such findings into wider scales of assessment (Brooks *et al.*, 2005). A number of recent studies are beginning to probe the enormous challenges of developing scenarios of adaptive capacity at multiple scales. Attainment of the Millennium Development Goals, particularly the first goal of eradicating extreme poverty and hunger, in the face of climate change will therefore require science that specifically considers food insecurity as an integral element of human vulnerability within the bio-physical systems, and that is able to offer usable findings for decision-makers at all scales.

Mitigation and Adaptation of Climate change in Ethiopia

Adapting Natural resource management practices to reduce vulnerabilities and facilitate adaptation to climate change is likely to incur additional costs, but these will probably be less costly than the costs of remedial actions (FAO, 2013). Adaptation and mitigation are two main responses to climate change. Adaptation measures are aimed to secure the continued delivery of natural resource goods and services, while mitigation could be reducing emissions from deforestation, and forest degradation; enhancing forest carbon sinks; and product substitution. The government started climate resilient green economy (CRGE) in 2011 that include production and distribution fuel wood saving efficient stoves, and establishment of plantation forest in some parts of the country (EPA, 2013). There are also several ways that help to adapt and mitigate climate change in Ethiopia and described as follows.

Creating climate smart landscapes for climate smart adaptation and mitigation to climate variability and change

For agricultural systems to achieve climate-smart objectives, including improved food security and rural livelihoods as well as climate change adaptation and mitigation, they often need to be take a landscape approach; they must become 'climate-smart landscapes'. Climate-smart landscapes operate on the principles of integrated landscape management, while explicitly incorporating adaptation and mitigation into their management objectives.

Studies on climate change dynamics related to agriculture suggests that three key features characterize a climate-smart landscape: climate-smart practices at the field and farm scale; diversity of land use across the landscape to provide resilience; and management of land use interactions at landscape scale to achieve social, economic and ecological impacts. To implement climate-smart agricultural landscapes with these features (that is, to successfully promote and sustain them over time, in the context of dynamic economic, social, ecological and climate conditions) requires several institutional mechanisms: multi-stakeholder planning, supportive landscape governance and resource tenure, spatially-targeted investment in the landscape that supports climate-smart objectives, and tracking change to determine if social and climate goals are being met at different scales. To achieve climate-smart landscape initiatives widely and at scale will require strengthened technical capacities, institutions and political support for multi-stakeholder planning, governance, spatial targeting of investments and multi-objective impact monitoring. This issue paper aims to advocate the urgency of creating climate-smart landscape for climate-smart agriculture (CSA).

Climate change can be addressed together by transforming agriculture by adopting practices that are "climate-smart". Climate-smart Agriculture (CSA) or Climate-smart farming techniques would increase farm productivity and incomes, and make agriculture more resilient to climate change, while also contributing to mitigation. Agriculture has to address simultaneously three intertwined challenges: ensuring food security through increased productivity and income, adapting to climate change and contributing to climate change mitigation. To accomplish this, food systems have to become, at the same time, more efficient and resilient, at every scale from the farm level to the global level. Radical changes are needed in agricultural and food systems. These changes can play an essential role in greening the economy and contributing to sustainable development. Agricultural production must increase if food supply is to keep pace with rapid population growth. Yet at the same time, it is clear that if the world is to meet its targets for reducing greenhouse gas emissions and mitigating climate change, agriculture must become 'climate-smart'.

The opportunities - climate-smart landscapes for climate-smart agriculture

As research and policy links between climate change and agriculture have advanced, 'climate-smart agriculture' has emerged as a framework to capture the concept that agricultural systems can be developed and implemented to simultaneously improve food security and rural livelihoods, facilitate climate change adaptation and provide mitigation benefits. Since it emerged in 2010, the development of this idea and use of the term itself has been led by international institutions, particularly the United Nations FAO and the World Bank. The Consultative Group on International Agricultural Research (CGIAR) has provided leadership to the international research community as the idea has matured.

While newly framed as a concept for the climate change and agricultural development communities, climate-smart agriculture includes many of the field-based and farm-based sustainable agricultural land management practices already in the literature and in wide use, such as conservation tillage, agro-forestry, residue management, and others. Most of the focus of climate-smart agriculture has been on the implementation of these field and farm practices, and the ways that they can be improved in the context of a changing climate. Many others are engaged in the discourse on agricultural practices for climate change adaptation and mitigation, but without using the climate-smart terminology. However, CSA requires actions beyond the farm scale. One element of FAO's definition is 'adopting an ecosystem approach, working at landscape scale and ensuring inter-sectoral coordination and cooperation'. In the World Bank's version, climate-smart agriculture includes 'integrated planning of land, agriculture, fisheries, and water at multiple scales (local, watershed, regional)'. Yet while landscapes are clearly considered a key component of the climate-smart conceptual framework, there have been few efforts to elucidate the mechanisms to implement climate-smart landscapes.

Conclusion and Recommendation

Climate change has already caused and will continue to cause changes in global temperature and precipitation patterns as well as changes in water cycle, forest growth, soil processes and properties as previously discussed.CC research should focus and identify tree species those are favored or negatively affected and need to be developed adaptation options such as silvicultural practices, tree breading and the like. Resistant species selection, tree breeding and propagation is the most important way to cope with climate change. Preparing for climate change will enhance the safety, well-being, and livelihoods of Ethiopian citizens.

One of the important causes for vulnerability of Ethiopia to climate variability and change is very high dependence on rainfall patterns and rain fed farming for food production. This is very sensitive to climate variability and change. The overall performance of the economy depends on the agricultural production. It also severely impacts the soil resources of the country and indirectly on the crop production. This in turn stands as a major stumbling block the country's economic growth and its developmental goals and poverty reduction efforts.

Changes in average temperatures and in precipitation patterns will also influence soil organic matter. There is the chance we will see negative impacts on physical and chemical properties of our soils that are essential for the production of food and fiber products. It is the inhabitants of developing countries who are least prepared to cope with a changing climate and with potential soil degradation due to climate change; developed countries are better equipped to mitigate those changes and cope than developing countries are.

Climate change is affects the productive capacity of forests by changing the species composition, season of growth (phenology), making susceptible to pest and disease attack, frost, drought. Climate change affects the livelihood of forest dependent communities by damaging the products and service obtained from the forest and causing species extinction. The impacts of climate change and climate variability on forest ecosystems are evident around the world and further impacts are unavoidable. The best solution is the use of short rotation timber species and selection of appropriate species to minimize cost of management. Climate change increases CO fertilization and water use efficiency for most forest trees species which are called C3 plants and then increase productivity. The damage of climate change to forestry is more than its benefit as the extinction of tree species could not be compensated by increased productivity. Hardwood species are more susceptible to drought than softwoods. Accordingly, Ethiopia in general has more of hardwood species and it requires concerted efforts to conserve and propagate genetically superior hardwood species with appropriate of species site matching.

Climate-change adaptation planning about current and future climate related impacts and vulnerabilities and wood production in Africa are hampered by a lack of information (IUFRO, 2010). Generally, physical, environmental and socioeconomic factors reduce timber productivity in dry tropics and sub tropics mainly by the limitation of moisture exacerbated by climate change, the less availability of soil nutrients due to land degradation, and the use of short rotation crops which may not produce quality timber.

Reference

Bathke J., Oglesby J., Rowe M., Wilhite A., 2014. Understanding and Assessing Climate Change: Implications for Nebraska. School of Natural Resources Institute of Agriculture and Natural Resources, *University of Nebraska–Lincoln, USA*. ISBN 1-56161-037-2

Brevik, E.C. 2012 Soils and climate change: Gas fluxes and soil processes. *Soil Horiz.*, *53*,doi:10.2136/sh12-04-0012.

Blum, W.E.H.; Nortcliff, S. Soils and Food Security. In *Soils and Human Health*; Brevik, E.C., Burgess, L.C., Eds.; CRC Press: Boca Raton, FL, USA, 2013; pp. 299–321.

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, 2007: Africa. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

Brevik, E.C. 2013; Climate Change, Soils, and Human Health. In *Soils and Human Health*; Brevik, E.C., Burgess, L.C., Eds.; CRC Press: Boca Raton, FL, USA, pp. 345–383.

Brady, N.C.; 2008; *The Nature and Properties of Soils*, 14th ed.; Pearson Prentice Hall: Upper Saddle River, NJ, USA,

Brevik, E.C.; Homburg, J.A. 2004; A 5000 year record of carbon sequestration from a coastal lagoon and wetland complex, Southern California, USA. *Catena57*, 221–232.

Brevik, E.C. 2009; Soil Health and Productivity. In *Soils, Plant Growth and Crop Production*; Verheye, W., Ed.; Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, EOLSS Publishers: Oxford, UK,. Available online: http://www.eolss.net (accessed on 10 May 2013).

Botkin, D.B., Saxe, H., Araujo, M.B., Betts, R., Bradshaw, R.H.W., Cedhagen, T. et al. (2007). Forecasting the effects of global warming on biodiversity.*Bioscience*, 57: 227–236.

Carney, K.M.; Hungate, B.A.; Drake, B.G.; Megonigal, J.P. 2007, Altered soil microbial community at 2 elevated CO2 leads to loss of soil carbon. *Proc. Natl. Acad. Sci. USA104*, 4990–4995.

Cerling, TE, Wang Y, Quade J. (1993). Expansion of C4 ecosystems as an indicator of global ecological change in the late Miocene. *Nature* 361: 344-345.

Coughenour, M.B.; Chen, D.-X.1997; Assessment of grassland ecosystem responses to atmospheric change using linked plant-soil process models.*Ecol. Appl.7*, 802–827.

Devereux, S. and S. Maxwell, Eds., 2001: *Food Security in Sub-Saharan Africa*. ITDG Publishing, Pietermaritzburg, 361 pp.

Di Baldassarre, G., Elshamy, M., van Griensven, A., Soliman, E., Kigobe, M., Ndomba, P., Mutemi, J., Mutua, F., Moges, S.,Xuan, J.-Q., Solomatine, D. &Uhlenbrook, S. (2011) Future hydrology and climate in the River Nile basin: a review. *Hydrol. Sci. J.*

56(2), 199–211.

Easterling, W.E.; Aggarwal, P.K.; Batima, P.; Brander, K.M.; Erda, L.; Howden, S.M.; Kirilenko, A.; Morton, J.; Soussana, J.-F.; Schmidhuber, J. 2007; Food, Fibre and Forest Products. In *Climate Change: Impacts, Adaptation and Vulnerability*; Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E., Eds.; Cambridge University Press: Cambridge, UK, 2007; pp. 273–313.

Eglin, T.; Ciasis, P.; Piao, S.L.; Barré, P.; Belassen, V.; Cadule, P.; Chenu, C.; Gasser, T.; Reichstein, M.; Smith, P. 2011; Overview on Response of Global Soil Carbon Pools to Climate and Land-Use Changes. In *Sustaining Soil Productivity in Response to Global Climate Change: Science, Policy, and Ethics*; Sauer, T.J., Norman, J.M., Sivakumar, M.V.K., Eds.; John Wiley & Sons, Inc.: Oxford, UK, pp. 183–199.

Ehleringer, J., Bjorkman, O. (1977). Quantum yields for CO2 uptake in C3 and C plants.dependence on temperature, CO2 and O2 concentration. *Plant Physiol.*,59: 86-90.

EPA (Ethiopian Environmental Protection Authority). (2012). National Report of Ethiopia, United Nations Conference on Sustainable Development (Rio +20).

EPI (Environmental Performance Index).(2012). Environmental Performance Index and Pilot Trend Environmental Performance Index (www.epi.yale.edu).

Farm Africa and SOS Sahel Ethiopia. (2007). The key Steps in Establishing Participatory Forest Management: A field manual …Best Prac series No.1. Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization).(2013). Climate change guidelines for forest managers. FAO Forestry Paper No. 172. Rome, Food and Agriculture Organiz.of the UN.

Gill, R.A.; Polley, H.W.; Johnson, H.B.; Anderson, L.J.; Maherali, H.; Jackson, R.B. 2002; Nonlinear grassland responses to past and future atmospheric CO2. *Nature417*, 279–282.

Gorissen, A.; Tietema, A.; Joosten, N.N.; Estiarte, M.; Peñuelas, J.; Sowerby, A.; Emmett, B.A.; Beier, C. 2004; Climate change affects carbon allocation to the soil in shrublands. *Ecosystems7*, 650–661.

Hatch, M.D. (1987). C4 photosynthesis: a unique blend ofmodified biochemistry, anatomy and ultrastructure. *Biochem.Biophys.Acta* 895: 81–106.

Hansen, J.; Sato, M.; Kharecha, P.; Russell, G.; Lea, D.W.; Siddall, M. 2007; Climate change and trace gases.*Philos. Trans. R. Soc. A*, *365*, 1925–1954.

Hungate, B.A.; Dukes, J.S.; Shaw, M.R.; Luo, Y.; Field, C.B. 2003; Nitrogen and climate change.*Science302*, 1512–1513.

IPCC (2007) Summary for Policymakers. In *Climate Change: The Physical Science Basis*; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L., Eds.; Cambridge University Press: Cambridge, UK,pp. 1–18.

IUFRO (International Union of Forestry Research Organization) 2010. Making African forests fit for climate change. A regional view of climate change impacts on forests and people, and options for adaptation: Policy brief. M.Kleine, A. Buck, C. Eastaugh (Eds.).

Jarvis, A.; Ramirez, J.; Anderson, B.; Leibing, C.; Aggarwal, P. 2010; Scenarios of Climate Change Within the Context of Agriculture. In *Climate Change and Crop Production*; Reynolds, M.P.,Ed.; CPI Antony Rowe: Chippenham, UK, pp. 9–37.

Jeannie S, Avner V, ErikaW, 2010 Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. Climatic Change 104:599–627 DOI 10.1007/s10584-010-9835-4 © Springer Science+Business Media B.V. 2010

Kaushal, S., G. Likens, N. Jaworski, M. Pace, A. Sides, D. Seekell, K. Belt, D. Secor, and R. Wingate. (2010). Rising stream and river temperatures in the United States. Frontiers in Ecology and the Environment 8: 461–466. doi:10.1890/090037.

Kirkham, M.B. 2011; *Elevated Carbon Dioxide*; CRC Press: Boca Raton, FL, USA.

Kurukulasuriya, P. and S. Rosenthal, 2003: Climate change and agriculture: a review of impacts and adaptations. Climate Change Series Paper 91,World Bank, Washington, District of Columbia, 106 pp

Lal, R. 2010; Managing soils and ecosystems for mitigating anthropogenic carbon emissions and advancing global food security. *BioScience*, *60*, 708–721.

Lal, R.; Kimble, J.; Follett, R.F. 1998; Pedospheric Processes and the Carbon Cycle. In *Soil Processes and the Carbon Cycle*; Lal, R., Kimble, J.M., Follett, R.F., Stewart, B.A., Eds.; CRC Press: Boca Raton, FL, USA, pp. 1–8.

Link, S.O.; Smith, J.L.; Halverson, J.J.; Bolton, H., Jr. 2003; A reciprocal transplant experiment within a climatic gradient in a semiarid shrub-steppe ecosystem: Effects on bunchgrass growth and reproduction, soil carbon, and soil nitrogen. *Glob. Change Biol.9*, 1097–1105.

Long, S.P.; Ainsworth, E.A.; Leakey, A.D.B.; Morgan, P.B. 2005; Global food insecurity. Treatment of major food crops with elevated carbon dioxide or ozone under large-scale fully open-air conditions suggests recent models may have overestimated future yields. *Philos. Trans. R. Soc. B*, *360*, 2011–2020.

Lovett, J.C.,Midgley, G.F., Barnard, P. (2005). African plant diversity and climate change. *Annals of the Missouri Botanical Garden* 92(2): 139-152.

Lukac, M., Calfapietra, C., Lagomarsino, A., FLoreto. (2010). Global climate change and tree nutrition: effects of elevated CO2 and temperature: Tr. ph. [0829-318X] 30: 1209 -1220.

MEA (Millennium Ecosystem Assessment). (2005). Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington, DC.

Mendelsohn, R., A. Dinar and A. Dalfelt, 2000b: Climate change impacts on African agriculture. Preliminary analysis prepared for the World Bank, Washington, District of Columbia, 25 pp.

Mullen, R.W. 2011; Nutrient Cycling in Soils: Nitrogen. In *Soil Management: Building a Stable Base for Agriculture*; Hatfield, J.L., Sauer, T.J., Eds.; Soil Science Society of America: Madison, WI,USA, pp. 67–78.

Niklaus, P.A.; Körner, C. 2004, Synthesis of a six-year study of calcareous grassland responses to in situ CO enrichment.*Ecol. Monogr.74*, 491–511.

Niklinska, M.; Maryanski, M.; Laskowski, R. 1999; Effect of temperature on humus respiration rate and nitrogen mineralization: Implications for global climate change. *Biogeochemistry44*, 239–257.

Norby, R.J.; Luo, Y. 2004; Evaluating ecosystem responses to rising atmospheric CO2 and global warming in a multi-factor world.*New Phytol.162*, 281–293.

O'Brien, K., 2006: Are we missing the point? Global environmental change as an issue of human security. *Global Environ. Chang.*, **16**, 1-3.

Pérez, M., Invers, O., Ruiz, J.M., Frederiksen, M.,Holmer, M. (2007). Physiological responses of the seagrass*Posidoniaoceanica*to elevated organic matter content in sediments: an experimental assessment. *J.Exp. Mar. Biol.* Ecol344:149-160.

Pimentel, D. 2006; Soil erosion: A food and environmental threat. *Environ. Dev. Sustain.*, *8*,119–137.

Price, D.T.; Peng, C.H.; Apps, M.J.; Halliwell, D.H. 1999; Simulating effects of climate change on boreal ecosystem carbon pools in central Canada. *J. Biogeogr.26*, 1237–1248.

Poorter, H.; Navas, M.-L.2003; Plant growth and competition at elevated CO2: On winners, losers and functional groups. *New Phytol.157*, 175–198.

Reddy, K.R., Hodges, H.F. (eds). (2000). Climate Change and Global Crop Productivity.ISBN 0 85199 439 3. CABI *Publishing* is a division of CABn*International.*

Reich, P.B.; Hobbie, S.E.; Lee, T.; Ellsworth, D.S.; West, J.B.; Tilman, D.; Knops, J.M.; Naeem, S.; Trost, J. 2006; Nitrogen limitation constrains sustainability of ecosystem response to CO2 *Nature*, *440*, 922–925.

St. Clair, S.B.; Lynch, J.P. 2010; The opening of Pandora's Box: Climate change impacts on soil fertility and crop nutrition in developing countries. *Plant Soil335*, 101–115.

Sanchez, P.A.; Swaminathan, M.S. 2005; Hunger in Africa: The link between unhealthy people and unhealthy soils. *Lancet*, *365*, 442–444.

Sievänen, R., Salminen, O., Kallio, M. (2013).The impact of round wood and fuel wood removals and climate change on the carbon balance of Finnish forestsa.*Finn For.Res Inst.*

Slingo, J.M., A.J. Challinor, B.J. Hoskins and T.R. Wheeler, 2005: Introduction: food crops in a changing climate. *Philos. T. Roy. Soc. B*, **360**, 1983-1989.

Sohngen, B, Mendelsohn, R., Sedjo. R (2001).A Global Model of Climate Change Impacts on Timber Markets.*J. Agr. R. Ec.*26(2):326-343.

Tan, Z.; Tieszen, L.L.; Liu, S.; Tachie-Obeng, E. 2010; Modeling to evaluate the response of savanna-derived cropland to warming-drying stress and nitrogen fertilizers. *Clim. Change*100, 703–715.

U.S. Global Change Research Program (USGCRP). (2009). Global Climate Change Impacts in theUnited States, [Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.)]. New York:Cambridge University Press. Retrieved from http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts.

Wan, Y.; Lin, E.; Xiong, W.; Li, Y.; Guo, L. 2011; Modeling the impact of climate change on soil organic carbon stock in upland soils in the 21st century in China. *Agric. Ecosyst. Environ.*141, 23–31.

Zaehle, S.; Friedlingstein, P.; Friend, A.D. 2010, Terrestrial nitrogen feedbacks may accelerate future climate change. *Geophys. Res. Lett.*37, L01401; doi:10.1029/2009GL041345.

Water Resource Evaluation and Investigation of its Quality and Sustainability for Irrigational purpose using GIS Technology Reference from Open hand dug wells and River Streams, a case study in Elala catchment, Northern Ethiopia, East Africa

Amanuel Gidey

Institute of Geo-Information and Earth observation Science, Mekelle University, Ethiopia.

(Email: amanuelgw19@gmail.com, Cell phone: 0914751663)

ABSTRACT

The existing water resources in Elala catchment is adversely affected due to rapid growth of population density, fast expansion of urbanization, chemical fertilizers, deforestation, very poor management of wastes and watershed management. To overcome these sever environmental problems, a systematic evaluation of water resource is essential for the proper utilization and management of the precious natural resources using GIS technology. GIS is efficient techniques for water quality and suitability; to facilitate better data analysis, map, interpolate, plan, combine data sets, manipulate, georeference, capture and interpretation. The objective of this study was to evaluate water quality and suitability for irrigation based on the assessment of pH, EC, TDS, Total alkalinity, Total hardness, Ca^{2+}, Na^{+}, $Mg^{2+,}$ K^{+}, $HCO3^{-}$, $CO3^{2-}$, Cl^{-}, $NO3^{-}$

Introduction

Water is a basic natural resource and a key factor for sustainable agricultural development and food security throughout the world. Agricultural irrigation is a major sector in green economic development of Ethiopia, as it is the source of livelihood for majority of the population. However, nowadays the rate of population growth of our planet is drastically increasing that affect the natural resources, landscape and environment of our unique planet. The existing water resources in Elala catchment is adversely affected due to rapid growth of population density, fast expansion of urbanization, industrialization, chemical fertilizers and pesticides from agricultural practice, domestic sewages, overgrazing, deforestation, salinity problem, very poor management of wastes and watershed management. Water pollution not only affects the water quality, but also affects the human health, economic development and social prosperity (Milovanovic, 2007). Similarly, the uncontrolled and excessive use of fertilizers and pesticides has long-term effects on water resources (Chapman, 1996).

To overcome these sever environmental problem and to sustainable agricultural development as well as to elevate irrigational production rate then to secured food security, water resource evaluation for its quality and suitability using GIS Technology is crucial. GIS not only facilitates data capture, analyzing, manipulating, georeferncing and processing, but also serve as powerful computational tools that facilitate multiple map integrations that make it very easy for people to understand a lot of complicated data with less investment of costs, energy and time.

The main objective of this study was to evaluate water quality and suitability for irrigational use based on the assessment of pH, EC, TDS, Total alkalinity, Total hardness, Ca^{2+}, Na^{+}, $Mg^{2+,}$ K^{+}, $HCO3^{-}$, $CO3^{2-}$, Cl^{-}, $NO3^{-}$ and $PO4^{3-}$, to provide spatial distribution map of water quality parameters using IDW technique, select suitable sites and to analyze level of suitability based on pH, EC, salinity hazard, sodicity hazard, bicarbonate hazard and specific ion toxicity problem. The protection of the water resources are matters of urgent to permit ecologically sensitive construction and sustainable socioeconomic development in the whole catchment. In this project the water quality was analyzed using GIS technology and mapped via Inverse Distance Weighed (IDW) spatial interpolation technique has been used to estimate the spatial distribution of the water quality parameters.

Materials and Methods

The co-ordinates and its elevation of the sampling location of the water samples were collected using Garmin hand held Global Positioning System (GPS) during field surveying. For analyzing the chemical aspects of water quality in the catchment, observation of different open hand dug wells and river streams have been selected for investigation throughout the catchment. The water samples were collected from thirty five, 13 from groundwater and 22 from surface water. All the water samples were collected in two liter plastic bottles which were washed and triple-rinsed with distilled water and with the collection water before sampling and transporting them to the laboratory.

The water samples were measured for its pH, EC, TDS, hardness, alkalinity and major ions including Ca, Mg, Na, K, Cl, NH4, NO3, NO2, PO4, SO4, CO3 and $HCO3^-$. The laboratory result concentrations were analyzed using AAS (Atomic Absorption Spectrophotometer), UV (ultra violet spectrophotometer technique), Titration and Calculation Methods. These analyses were carried out in Geochemistry Analytical Laboratory of Earth Sciences Department in Mekelle University. Water quality and suitability for irrigation purpose to measure the concentration of the water quality parameters was assessed using Wilcox, (FAO, 1985, reprinted in 1989), Sawyer and McCarty, Eaton and USDA guideline standards. Sodium absorption ratio (SAR) takes EC and percent sodium (%Na) to other cations in to consideration for rating of water for irrigation use; Residual sodium carbonate (RSC) by Eaton takes values of calcium, magnesium, carbonate and bicarbonate in to consideration to classify water for irrigation.

Where, ionic concentrations of the major ions are expressed in terms of epm.

$$SAR = \frac{Na^+}{\left[\frac{(Ca^{2+} + Mg^{2+})}{2}\right]^{0.5}}$$

$$\%Na = (Na^+ + K^+)*100/(Ca^{2+} + Mg^{2+} + Na^+ + K^+)$$

$$RSC, meq/l = (HCO3^- + CO3^{2-}) - (Ca^{2+} + Mg^{2+})$$

The result of the laboratory analysis were analyzed, processed and presented using software packages like ArcGIS, Arc hydro, ERDAS, Aquachem, SPSS, Microsoft word and Microsoft excel.

Result and Discussion

Assessment of water quality and suitability for irrigation purpose using GIS technology

The chemical quality of water is a key factor to determine the suitability of water for irrigational use. The concentration and composition of dissolved constituents in water determine its suitability for irrigation purpose. The concentration of Electrical conductivity (EC) and Total dissolved solids (TDS) were used to evaluate the salinity of the water for irrigational use.

The range of EC and TDS of the catchment shows that, there were an increasing both its value and variability as one goes from upper scenario to down scenario of the catchment, particularly around Mekelle city and around it. For the increment of EC and TDS concentration might be due to some anthropogenic effects and geological source.

Generally evaluation of water quality and its suitability to irrigational use was determined based on alkalinity, hardness, salinity hazard, sodium hazard, bicarbonate hazard, specific ion toxicity hazard and slope suitability analysis.

Salinity Hazard

The total concentration of soluble salts in irrigation water can be expressed in terms of EC and TDS for purposes of diagnosis and classification irrigation water. Classification of water based on salinity hazard was done according to the recommendation of (FAO,1985 and 1989), (Sadashivaiah et al., 2008) and (Wilcox, 1955).

According TDS concentration value less than 450 mg/l suitable water class, from 450 to 750 mg/l is slight to moderate water class, between 750 to 2000 mg/l permissible water to irrigation, but water containing more than 2000 mg/L of TDS concentration value unsuitable water class to irrigation. Based on salinity classification result 71.43 % doubtful water class (hardly suitable), 14.29 % good water class, 11.43 % unsuitable water class and 2.86 % excellent water class to irrigational use. Based on salinity assessment most of the water samples in the catchment were within the prescribed limit suitable and permissible water class except some water samples that had been their concentration values above the desirable limit to irrigational use. Similar this result had been reported in Jaffna Peninsula in Sri Lanka by (Nishanthiny et al., 2010).

Sodium hazard (Sodicity hazard)

SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for sodium hazard. The higher the Na in relation to Ca and Mg, the higher the SAR, and the poorer the water infiltration. Sodium Adsorption Ratio (SAR) was computed for each water sample from the analyzed sodium (Na^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) using the derived calculations stated in (Lloyd and Heathcote, 1985).

Based on SAR irrigation water classification <= 10 meq/l suitable water class 1 (S1), between 10-18 meq/l medium water class 2 (S2), from 18-26 meq/l doubtful water class 3 (S3) and equal or greater than 26 meq/l water class 4 (S4) unsuitable water for irrigation according (USDA, 1954b) standard.

Regarding on sodium adbsorption ratios (SAR) the water samples of the catchment were classified under class 1 (S1) its concentration values were less than 10 meq/l. Therefore, based on SAR most of the water samples of the catchment fall in suitable category to irrigation use. By (Sultana et al., 2009) in Muktagacha Upazila in

Bangladesh had been also reported the same this result.

Total Hardness and Alkalinity

Hard water is not suitable for irrigational use. The hardness in the catchment was ranging from 544 to 1,070.0 mg/l with average mean 653.6 mg/l. According to (Sawyer and McCarty, 1976) all the water samples of Elala catchment exceed 300 mg/l which were considered to be very hard water class to irrigation use. The alkalinity of water is a measurement how the water is capable to neutralize acids and this is due to the presence of bicarbonates. High alkaline water with concentrations ranging above 300 mg/l was observed in the catchment, this might be due to decay of organic matter, weathering of rocks and minerals.

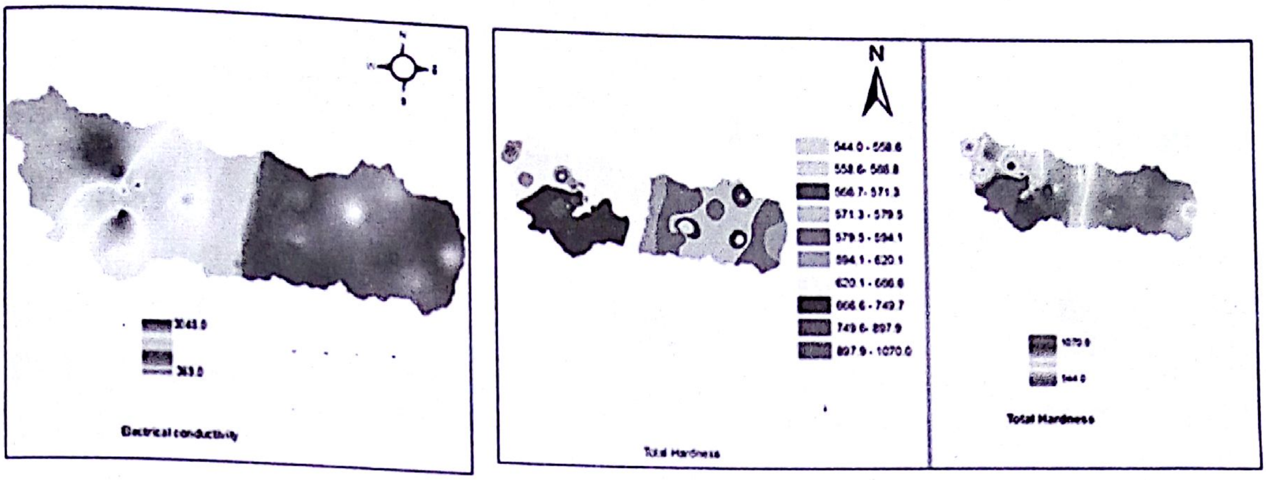


Figure 1 Spatial Distribution Map of Electrical Conductivity and Total Hardness

Bicarbonate Hazard

Water having high concentration of bicarbonates, there is a tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. Irrigation water with Residual Sodium Carbonate (RSC) < 1.25 meq/l is considered as suitable water class, between 1.25 to 2.50 meq/l classified as doubtful water class and > 2.50 meq/l classified as unsuitable water for irrigational use (Eaton, 1950) and (USDA, 1914, 1954a)). Based on the guidelines proposed by Eaton (1950) and (USDA, 1914 and 1954), the water in the catchment was classified under good irrigation water quality which can be used for all irrigation types without any restriction. In Jaffna Peninsula in Sri Lanka by (Sutharsiny et al., 2012) and in Maniyad Reservoir of Parala Village in INDIA by (Aher and Deshpande, 2011) also done the same case.

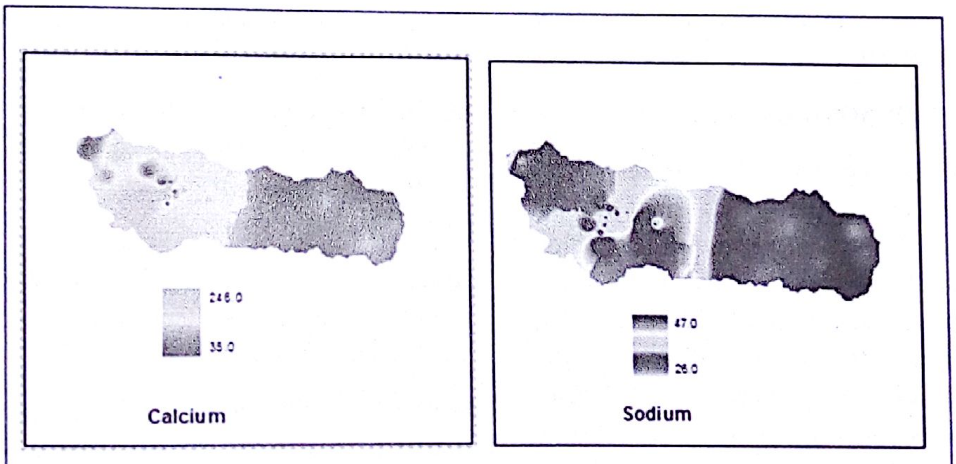
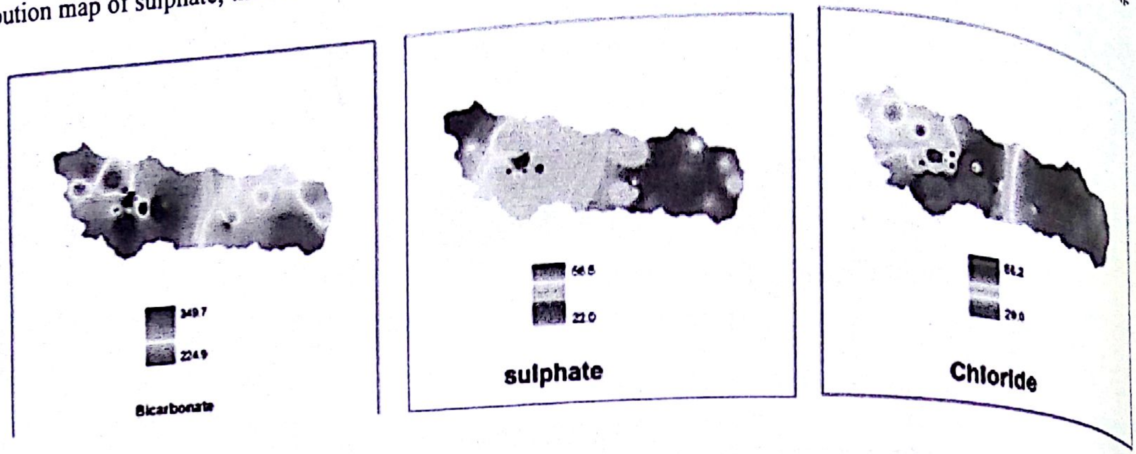


Figure 2 Spatial Distribution Map of Calcium and Sodium Concentration

From the above spatial distribution map of Calcium, it was observed that an increasing calcium concentration from upper scenario to down scenario of the catchment. The increasing concentration of calcium in down scenario of the study area might be due to gypsum dissolution and carbonate sources from the geological formation and anthropogenic effects from factories and industries. As well as I have understand from figure 2 the spatial distribution map of sodium there was high sodium concentration distribution especially around Mekelle city. concentration distribution especially around Mekelle city. This might be due to human induced activities. From the bellow spatial distribution map of bicarbonate concentration there was an increasing bicarbonate concentration along the surface water flow path. This might be due to geological information and carbonate weathering. From the below spatial distribution map of sulphate, there was low in western and high in eastern part of the watershed. From the spatial distribution map of chloride there was high chloride concentration distribution around Mekelle city. The chloride concentration was fluctuating between 29 to 56.2 mg/l. High concentration of chloride was observed in the downstream of the watershed. This might be due to human inducing activities.



Specific Ion Toxicity hazards (Chloride and Sodium)

Toxicity normally results when the toxic ions are taken up with the soil water and accumulate in the leaves during water transpiration to an extent that can damage the plant. The usual toxic ions in irrigation water are chloride, sodium etc. Sprinkler irrigation may cause special toxicity problems due to sodium and chloride being absorbed through the leaves. This occurs typically during periods of high temperature and low humidity. The leaf absorption speeds the rate of accumulation of a toxic ion and might be a primary source of the toxicity.

Slope suitability evaluation to irrigation

Slope had been considered as one of the evaluation parameters in irrigation water suitability analysis. There are four slope suitability classes (0-2%= S1 highly suitable slope class, 2-5%= S2 moderately suitable, 5-8%=S3 marginal suitable and >8%=N not suitable slope class to irrigation). According slope result, from the total area 39 km^2 is highly suitable, 141.50 km^2 moderately suitable, 47 km^2 marginal suitable, 113.25 km^2 is not suitable to irrigational use. The overall view of the water quality and suitability investigation for irrigation use of the present study indicated that most of the water samples in the catchment have good quality water for irrigation use, but also unsuitable water to irrigation purpose such as salinity hazard, hardness, alkalinity problems.

Reference

Aher, K. R., and Deshpande, S. M. (2011). Assessment of Water Quality of the Maniyad Reservoir of Parala Village , district Aurangabad : Suitability for Multipurpose Usage. **1**, 6-17.

Ayres, R.S, D.W, and Westcot (1985). Water Quality for Agriculture. Irrigation and Drainage Paper No. 29. *Food and Agriculture Organization of the United Nations*, Rome.pp.1-117.

Chapman, D. (1996). Water Quality Assessment. A Guide to the use of Biotic,Sediments and Water in Environmental Monitoring 2nd.ed., Chapman and Hall,London.

Eaton (1950). Significance of Carbonate in Irrigation Water. Soil Sci. 67:112-133.

FAO (1985, reprinted in 1989). Water quality for agriculture. FAO irrigation and drainage paper 29 Rev. 1. Food and Agriculture Organization of the United Nations, Rome, Italy.

Lloyd, J. W., and Heathcote, J. A. (1985). Natural Inorganic Hydrochemistry in Relation to Groundwater. *Oxford Press Oxford*, 296 pp.

Milovanovic (2007). Water quality assessment and determination of pollution sources along the Axios/ Vardar River, South-eastern Europe. Desalination, 213, pp159-173.

Nishanthiny, S. C., Thushyanthy, M., Barathithasan, T., and Saravanan, S. (2010). Irrigation Water 9. Quality Based on Hydro Chemical Analysis , Jaffna , Sri Lanka National Water Supply and Drainage Board , Jaffna , Sri Lanka. **7**, 100-102.

Richards, L. A. (1954). Diagnosis and improvement of Saline and Alkali soils. Agriculture Handbook no 60. United States Department of Agriculture, United States of America,160 p.

Sadashivaiah, C., Ramakrishnaiah, C. R., and Ranganna, G. (2008). Hydrochemical analysis and evaluation of groundwater quality in Tumkur Taluk, Karnataka State, India *Intl.J.Environ. Research and publication health 5 (3) : 158-164*

Sawyer, C. N. a., and McCarty, P. L. (1976). Chemistry of salinity engineers, New York, USA.

Sultana, N., Haque, M. A., and Elahi, S. F. (2009). Evaluation of surface irrigation water quality in Muktagacha Upazila of Bangladesh. **31**, 100-102.

Sutharsiny, A., Pathmarajah, S., Thushyanthy, M., and Meththika, V. (2012). Characterization of Irrigation Water Quality of Chunnakam Aquifer in Jaffna Peninsula. **23**, 237-248.

USDA (1954a). U.S. Salinity Lab. Staff., Diagnosis and improvement of saline and alkali soils *Hand book-60*, p. 160.Sutharsiny, A., Pathmarajah, S., Thushyanthy, M., and Meththika, V. (2012). Characterization of Irrigation Water Quality of Chunnakam Aquifer in Jaffna Peninsula. **23**, 237-248.

USDA (1954a). U.S. Salinity Lab. Staff., Diagnosis and improvement of saline and alkali soils *Hand book-60*, p. 160.

USDA (1954b). U.S. Salinity Lab. Staff., Diagnosis and improvement of saline and alkali soils Hand book-60, p. 160.

Wilcox (1955). Classification and use of Irrigation Waters, U.S.Dept.Agri.Circ.969, Washington, D.C.

"Urban Domestic Wastewater Treatment Using Waste Stabilization Pond Technology With The Help of RS and GIS Application, In The Northern Ethiopia, Tigray Regional State, Mekelle City"

Amare G/Medhin, Lecturer of Geo_Information System, Mekelle University

Email: amarenigusse@yahoo.co.uk

Cell phone: 0932163507

Institute of Geo_Information and Earth Sciences

Introduction

Urban wastewater management has been one of the major environmental problems in many parts of the world. This problem is more severe in developing countries where there is rapid population and economic growth especially in the urban centers which in turn results in production of excess unmanaged urban wastewater. However, the provision of services including wastewater collection and treatment are not kept in pace with rapid population and economic growth which (Masudi, *et al*., 2011).

It is estimated that 90 % of all wastewater in developing countries is discharged directly into rivers, lakes or oceans (Corcoran, *et al*., 2010). Such discharges are part of the reason why deoxygenated dead zones are growing rapidly in the seas and oceans. Untreated wastewater is the missing link to meet the sanitation challenge. Some of the likely adverse effects of discharging of wastewater in to water bodies include; problem on human health, loss of fish life, ecosystem degradation and ultimately led to loss of water resources (Hodgson, 2007).

A study conducted by Lyse (2003) revealed that nine out of every ten African Cities are facing up serious wastewater disposal and treatment mechanism problem. Like other African Cities, the Ethiopian Towns have been experiencing similar serious problem of urban wastewater disposal and treatment mechanism. The study area, Mekelle City lacks proper infrastructures for collection and treatment of urban wastewater so that the wastewater released from different sectors join the urban drainage of the city that finally flows to the Ellala River. However, such practices have the potential to contaminate groundwater table, groundwater reservoirs and surface water bodies that create health problem to the surrounding society (Derbew, et *al*., 2006). This problem is mainly emanated due to the absence of piped sewerage line network and treatment site mechanism. In general, the city is facing up severe problem especially in the management of domestic wastewater. Hence, the overall sanitary situation of the city can be described as poor and urgent intervention on this situation is highly recommended (AGCCHEA and HYWASE, 2008).

In order to minimize this impact, wastewater treatment establishment is an essential means to cope up with the rising challenges. WSP is among the different means of urban domestic wastewater treatments which is the most simple, least cost and widely used especially in the tropics and sub tropics regions of the world (Corbitt, 2004; Gemitzi, *et al*., 2007). Therefore, to select suitable site for WSP, GIS tool is used to analyze the multicriteria variables. Generally, the aim of this study was to identify suitable sites for waste stabilization pond (WSP) and to analyze the WSP suitability of the study area using the RS and GIS technique

Methodology

The primary data used for this study were collected using GPS, personal observation and discussion with experts of the municipality. GPS was used to collect GCP (Ground Control Points). The secondary data used include hydrogeology, groundwater, soil depth, DEM, Quickbird and Landsat TM satellite images and admistrative boundary were collected from different organizations to drive the important parameters. Table 8 below shows the data types and their sources.

Table 1 Data types and sources

No.	Type of Data	Source of data	Spatial resolution/scale	Date Acquisition/Production
1	Quickbird Image	Mekelle University	5 m	2010
2	Landsat TM	Mekelle University	15m	2008
3	DEM	USGS	90 m	2007
4	Hydrogeology	EIGS	1: 100,000	1975
5	Soil depth	HTSL	1: 50,000	1975
6	Tigray topo map	EMA	1: 120,000	2011
7	Groundwater	Tigray_Water Resource Enterprise	1: 100,000	2006

The materials used throughout the research activities from early data collection to the final analysis and compilation of the final paper were GPS, Software packages (including ArcGIS 9.3 , and ERDAS Imagine 9.3 and Coordinate Convertor).

To select proper and reliable site for urban domestic wastewater treatment (Waste Stabilization Pond), nine variables were considered to develop WSP model. Those include depth of water table, soil permeability, slope, elevation, soil depth, LULC, settlement distance, road distance and river distance which were collected from different sectors. Visiting field was undertaken to collect 10 GCP samples randomly taken from the existing land uses (town, agriculture and forest) with total number of 30 GCP to make supervised classification. And, once these field data and thematic maps had been collected, ArcGis 9.3 and ERDAS 9.3 imagine were used for data preparation. Preprocessing images (geometric and radiometric correction) was carried out for Quick bird and Landsat TM prior to analysis.

Then, the collected satellite images (Quickbird and Landsat TM were receptively used to drive feature class (settlement area , road and river) from Quickbird through digitizing and Landsat TM to make land use land cover classification. DEM image was also used to drive slope and elevation. While the remaining thematic maps (soil texture, depth of water table and soil permeability) were used to drive feature class through digitizing after they have been scanned and georefernced. Arc GIS 9.2 was used for data preparation (digitizing, classification and reclassification) and suitability analysis (modeling) whereas ERDAS Imagine 9.3 was applied to make supervised classification in order to generate land use land cover class.

Data Analysis

During WSP suitability analysis, different baseline maps were generated using the ArcGis 9.2 and ERDAS 9.3 tools from different existing maps and images. Those map layers were classified, reclassified and finally rasterzied in the Arc map of ArcGIS. Then, weighted value estimation using linear combination formula was carried out in order to compute percentage influence variables. However, ranking of variables were a precondition for weighted value determination and was undertaken by the local expert's judgment. After computing weighted value of each variable, normalized weighted value of each variable was calculated using linear combination formula. Finally, percentage influence of variables were obtained by multiplying **parameters** normalized weighted value (PNWV) by hundred percent or it can be abbreviated as PNWV * 100%.

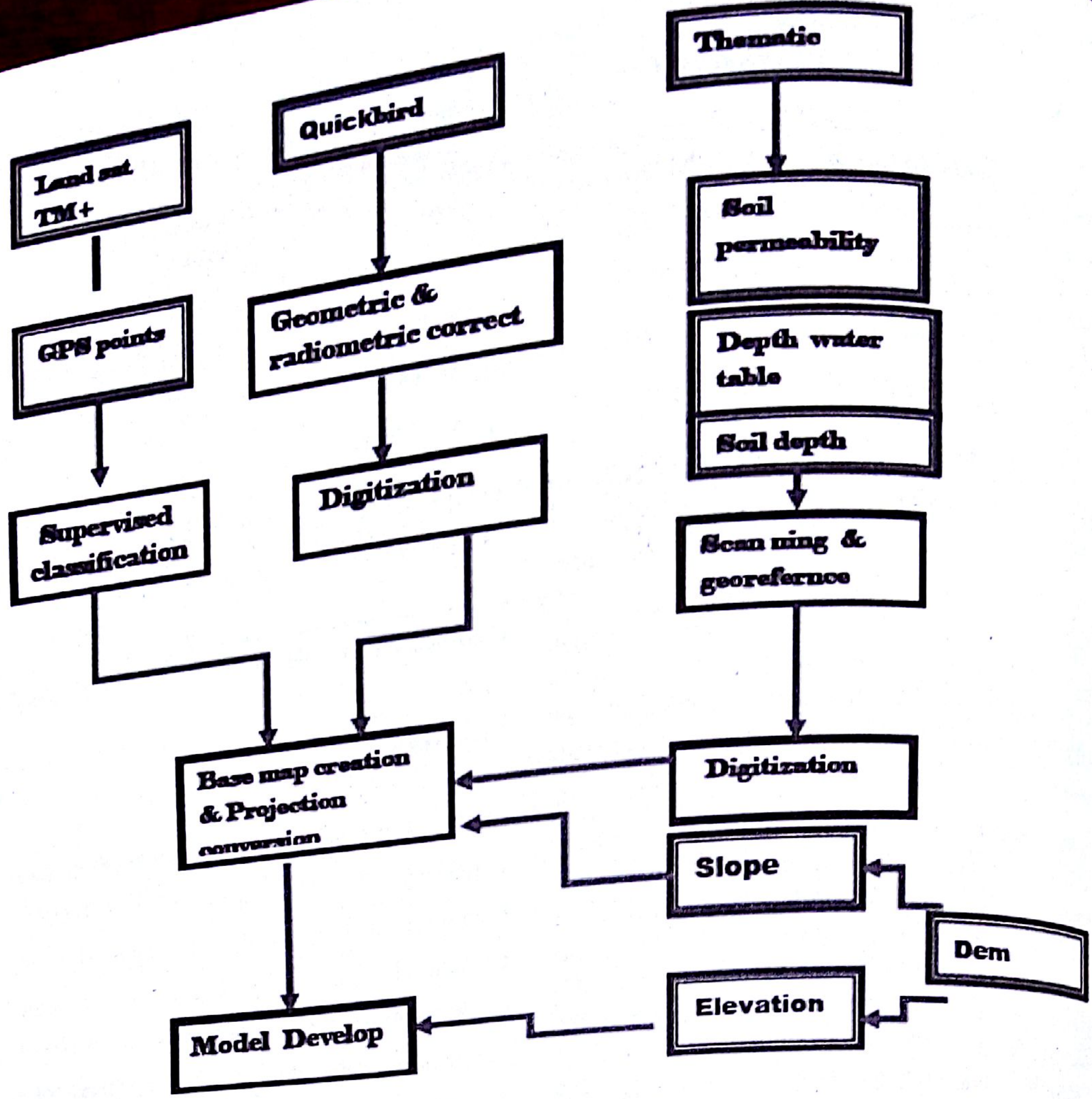


Figure 1. Chart flow methodology adopted

There is no universal commonly accepted standard criteria classification on WSP establishment in national or international level. The suitability classes of factors for this study were modified from international guidelines of land fill selection. Table 8 shows factors classification and suitability for WSP site selection modified from international guideline of landfill site selection (Oelzschner and Mutz , 1994; Oweis and Khera , 1998).

Source ; (Oelzschner and Mutz , 1994; Oweis and Khera, 1998)

The weighted value of each criterion was estimated based on the following formula.

$$W_j = (n - r_j + 1) / \Sigma (n - r_k + 1) \qquad \ldots 1$$

Where w_j , is normalized weight for the j^{th} criterion

n, is the number of criterion under consideration (k=1,2,3....n)

rk, the ranking position of the criterion

Each of these criterions was weighted by (n-rj+1) and normalized by the sum of all weights which is Σ (n-rk+1). Table 3 Weighted values of variables

Result and Discussion

3.1 Identification of Potential Areas for WSP Establishment

In this study, it was found that the city has large amount of alternative places for establishing waste stabilization pond. There are five class category of suitability of WSP, very high suitable, high suitable, moderate, low and very low suitable areas.

Table 2 Factors considered and their suitability classes

No.	Factors Considered	Suitability Classes				
		Very high	High	Medium	Low	Very low
1	Slope (%)	0 – 10	11 – 20	21 – 25	26 – 40	41 – 60
2	Soil permeability (m/h)	< 5	5-15	16-30	31-50	>50
3	Depth of water table	Above 30	21-30	16-20	10-15	<10
4	Elevation(m)	1932-2034	2035-2100	2100-2163	2163-2221	2221-2313
5.	Soil depth(cm)	150-120	120-90	90-60	60-30	<30
6.	Distance from road(km)	>=5	5-3	3-2	2-1	< 1
7	Distance from settlement (km)	>=5	5-3	3-2	2-1	< 1
8	Distance from road (km)	4-3	3-2	2-1	1	>4 & <1
9	LULC Vegetation				X	

Each of these criterions was weighted by (n-rj+1) and normalized by the sum of all weights which is Σ (n-rk+1). Table 3 Weighted values of variables

No.	Criterion	Straight Rank	Weight	Normalized weight	% influence
1	Depth of water table	1	9	0.2	20
2	Soil permeability	3	7	0.1555	15.6
3	Soil depth	6	4	0.0888	8.9
4	Slope	4	6	0.1333	13.3
5	Elevation	2	8	0.1777	17.8
6	Distance from road	8	2	0.0444	4.4
7	Distance from river	5	3	0.1111	11.1
8	Distance from settlement	7	5	0.0666	6.7
9	LULC	9	1	0.0222	2.2
Sum		45	45	1	100

From the above map of WSP suitability, the most suitable sites lie in the North West and Northern parts of the study area whereas the least unsuitable sites are found in the East and South parts of the study area. This implies that there are constraint variables that hinder WSP site selection and finest variables that favor WSP selection.

The result of the study exemplified that depth of water table, elevation, soil permeability and slope are found the most determinant parameters affecting WSP site selection having 20%, 17.8%, 15.6% and 13.3% of influence respectively that accounts 66.7% of the total variable's influence.

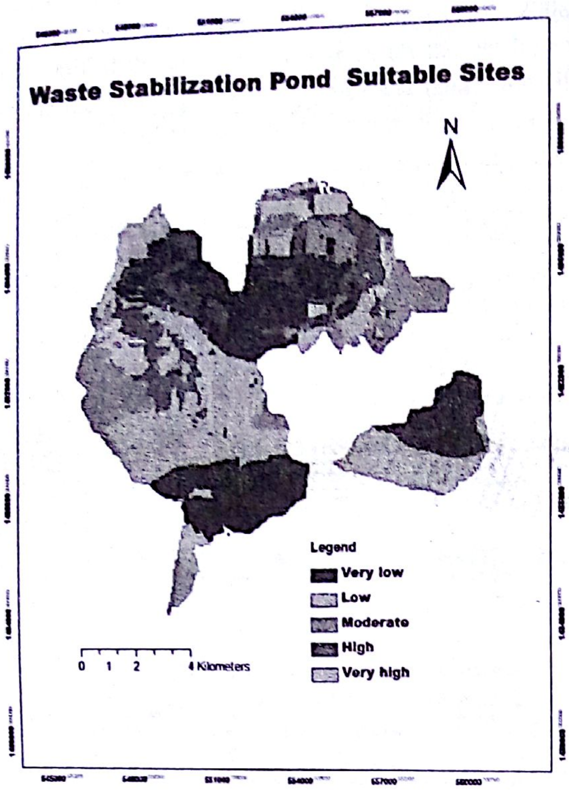


Figure 2 WSP Suitability Sites

The topographic factors like slope and elevation were also found very crucial factors during WSP site selection. In fact, it is unfeasible to select a WSP site without considering slope and elevation since water always flow from high altitude to low altitude. The finding demonstrates that areas with lower elevation and flat gradient were found more preferable for WSP selection. In contrast, areas with high elevation and steep gradient were found mostly unsuitable for WSP establishment. Similar study conducted by Amare (2011) noted that areas having slope that doesn't allow positive flow were considered as unsuitable while areas allow positive flow were considered suitable for urban runoff treatment establishment.

The outcome of the study depicted that depth of water table and soil with low rate permeability of water are preferable due to less percolation of wastewater. But, incase soils have high rate of permeability; water table can be highly affected by leachate from landfills (KCC, 2000). Moreover, a study by Javaheri, *et al*. (2006) believed that soils having high rate of permeability are considered as unsuitable while soils with very low permeability are an optimal to landfill site selection. A study on land application for wastewater treatment by Meinzinger (2003) stated, "a site with a greater soil depth shows better purification capacity than a site with a lower soil depth which is appropriate for land application." This implies that the site for WSP and landfill establishment has more similarity.

Furthermore, the study demonstrated that 66.7% influence is held by depth of water table, elevation, soil permeability and slope whereas the remaining 33.3% is detained by land use type, soil depth, road distance and river distance. Those variables have small percentage of influence in WSP site selection, LULC (2.2%), distance to road (4.4%), distance to settlement (6.7%), soil depth (8.9%) and distance to river 11.1% and hence have less impact in determining WSP site selection.

A study on urban runoff treatment establishment in Bahir Dar City by Amare (2011) used variables such as distance to settlement, elevation, slope, distance to river, distance to road and LULC. Among those given parameters, distance to settlement was given the highest percentage of influence followed by elevation and slope which is different with this WSP study. This may be due to the less impact of topographic factors since Bahir Dar City is more or less flat. In contrast, LULC was given the least percentage of influence which is similar for this WSP selection, too. Other study on landfill site selection by Nakakawa (2006) also found that LULC has the lowest percentage of influence since LULC could be compromised.

Further study by Meinzinger (2003) on wastewater treatment site selection stated that "soil type, land use and depth of water table had little influence in land application of wastewater although the last one was found to be very critical where high potential of water table prohibits the wastewater land application establishment." The finding showed that as distance is increased from road, settlement and river, it found that the suitability of WSP is also increased because it results in less environmental pollution. Public opposition decays exponentially when distance increases (Javaheri, *et al*., 2006).

Similar study was carry out in WSP site selection in Greece. During WSP site analysis five important parameters namely slope, land use type, soil permeability, distance to road and cities were considered (Gemitzi, *et al.*, 2007). However, the study conducted in Greece is different as compare with this study. That study was used the criterion without any estimation of variables weighted value (percentage influence) which is not more sound and scientific in WSP suitability so that all criterion were had equal percentage. But, the study held in Ethiopia, Mekelle City used weighted value estimation of variables using the linear combination formula. The second important difference was class suitability of variables were also different within this study. This is because there is no universal commonly accepted guideline on how to establish WSP sites.

Other study was also conducted in site suitability assessment for central anaerobic treatment in Thailand which is one part of WSP system (Yuttitham, *et al*, 2003). During the study, they used variables like transportation, land use, distance to river, distance to settlement, distance to pig farm and waste source were considered when WSP was selected. The study had more similarity within this study conducted in Ethiopia, Mekelle City in the way of methodology used, data analysis and finding. The weighted values of variables were determined by applying the liner combination formula so that factors percentage of influence was easily identified. Accordingly, distance to river was found the most influential factor. In contrast, land use was found the least influential factor which is exactly concise with this study.

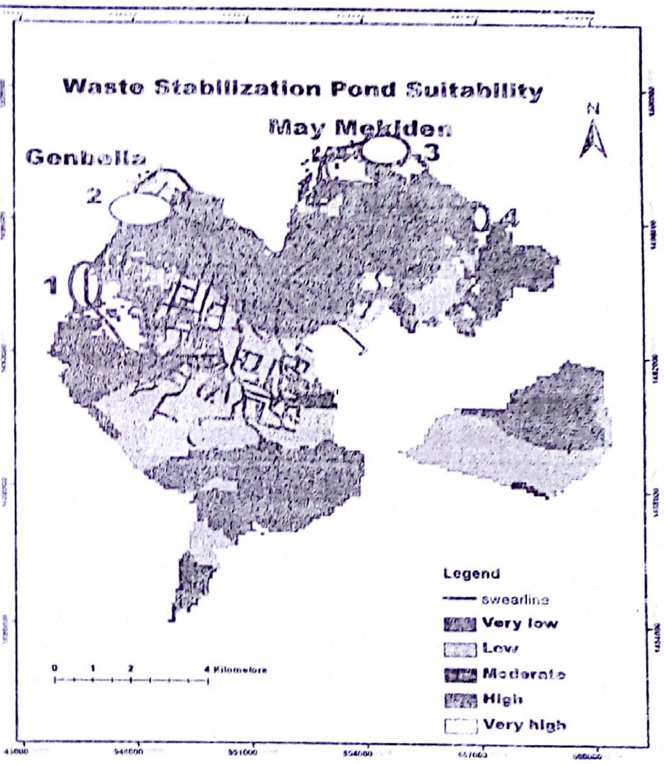
3.2 Analysis of WSP Sites

The total area of the study area is 108 km^2. Out of this area, 21.3% is suitable for WSP setting up while 51.3% is unsuitable and the remaining 27.5% is moderately suitable areas. Most of those unsuitable sites are characterized by steep slope, shallow depth of water table, high soil permeability and shallow soil depth which are considered as constraints for WSP selection. The table below shows area in (km^2), number of polygon and suitabilbbity in terms of percentage of WSP selection.

Table 4 WSP (area and suitability)

Suitability Class of WSP	Area in km^2	Suitability (%)
Very High	8.2	7.6
High	14.8	13.7
Moderate	31.5	29.2
Low	20.6	18.2
Very Low	34.9	32.3

Therefore, the city has large enough area for WSP establishment. However, the specific size and service year or duration of WSP is depend on mean minimum monthly temperature , the population growth and wastewater effluent discharge (Economopoulos and Tsihrintzis, (2002,2004). From the figure 4 below most of the potential and efficient sites are located in the North West and Northern parts of the study area. The lowest elevation found the most suitable areas is represented by NO. 1 even though areas represented by No. 3 and 4 represent potential areas, it is difficult practically to apply since the swerline outlet lie in the North West which is marked by 1 and 2.



Conclusion and Recommendations

The objective of this study was to establish WSP site, to do so nine significant parameters were carefully analyzed to select an ultimate site for treating urban domestic wastewater of Mekelle City. Those parameters are listed out in table three with their weighted values and percentage of influence.

The result map figure two and three indicate that North West and Northern parts of the study area are the most effective site for WSP whereas the Eastern and Southern parts are the least suitable sites. During the process of treatment site selection, depth of water table, elevation, soil permeability and gradient were found the most determinant factors while LULC and road distance were

Figure 3 WSP Suitability and Swearline Network among the least influential parameters. Out of the total area, 21.3% were found suitable and the remaining 51.3% were unsuitable. So, this implies that the city has large potential area that can be used for WSP establishment. In principle WSP consists of series ponds which are an excellent means of urban domestic wastewater treatment. Finally, every household's domestic wastewater or septic tank will be directly connected with the sewerline network to discharge to selected WSP sites.

The following recommendations had been forwarded based on the findings of the research.

- Most of the suitable candidate areas are located in the North West part of the study which is characterized by low elevation and flat gradient. So, before inauguration and implementation of WSP activities, assessment of flood vulnerability is precondition task that the concerned bodies should make sure.

- In this study the size area and duration (service year of WSP) is not determined because of absence of relevant data. Therefore, further assessment need to be carried out in areas related with this issue..

- The water released from WSP treatment site is not advisable to use for irrigation, washing and other purposes before checking the water quality in laboratory.

Most of the sites are found in the margin of the city where there are farmers so that awareness creation to the local people should be under taken before commencing this project unless it may affect them.

References

AGCCHEA and HYWASE, (2008). Mekelle liquid waste management feasibility report

Amare Sisay , (2011). *GIS based site suitability assessment for establishment of Biorentation system, the case of Bahir Dar Town.* Unpublished MSc. thesis, Bahir Dar University, Ethiopia.

Corbitt, R. A., (1994). *Standard handbook of environmental engineering (2nd* Edition). McGRAW Hill, New York

Corcoran, E., Nellemann,C., Baker, E., Bos, R. D. , Osborn, H. S. , (2010). *Sick water? The central role of wastewater management in sustainable development. A rapid response assessment.* United Nations Environment Programme, the Netherlands.

Derbew, F., Epstein, P. and Schaeffer, M., (2006). *Infrastructure inventories for Mekelle Town.* The urban institute, Washington D.C.

Gemitzi , A., Tsihrintzisb, V. A., Christou ,O. and Petalas C., (2007). Use of GIS in setting stabilization pond facilities for domestic wastewater treatment. *Journal of Environmental Management* ,82, Pp. 155–166.

Hodgson, I.O., (2007). *Performance of the Akosombo Waste Stabilization Ponds in Ghana.* SIR Water Research Institute. Accra, Ghana.

Javaheri , H., Nasrabadi , T., Jafarian , M. H., Rowshan , G. R. and Khoshnam , H., (2006). Site selection of municipal solid waste landfill using analytical hierarchy process methods in a geographical information technology environment in Giroft, Iran. *J. Environ. Health. Sci. Eng. 3(3) , Pp. 177-184.*

KCC, (2000). Environment impact statement for the proposed extension to Mpererwe sanitary landfill. KCC Library.

Lyse, O., (2003).*Waste disposal haunts cities,* the Times of Zambia. Retrieved from http://allafrica.com/stories/200303050103.html. Accessed [12/1/2012].

Masudi, A.S., Mashauri, D.A., Mayo, A.W. and Mbwette, T.S. , (2011). Constructed wetlands for wastewater treatment in Tanzania. WSP & CW Research Project, *University of Dare Salaam, Tanzania.*

Meinzinger, F., (2003). *GIS based site identification for the land application of wastewater of Christchurch city.* MSc. thesis, Lincoln University, New Zeeland.

Nakakawa, A., (2006). *A spatial decision support tool for landfill site selection for municipal solid waste management.* A project report submitted to school of graduate studies in partial fulfillment for the award of MSc. degree in Computer Science, Makerere University, Uganda.

Oelzschner.H and Mutz,(1994). Guideline for an appropriate management of domestic sanitary landfill sites publications. Deutche Geselis Chafit Fur Tecnische Zusammenarbit (GTZ), Germeny.

Oweis, I.S. and Khera, R.P. (1998). Geotechnology of waste management (2nd edition). PWS publishing company, London, UK.

Yuttitham, M., Tripetchkul,S., Gale,G. A., Chaiprasert, P., Tanticharoen ,M., and Silapathong ,C.(2003). Site suitability assessment for a central anaerobic treatment facility for biogas production in Nakhonpathom Province, Thailand. Proceedings of the 2nd regional conference on energy technology towards a clean environment 12-14 february 2003, Phuket, Thailand.

Rural water supply and its challenges in developing economies

(Review Paper)

Beshah M.Behailu

Abstract

This review paper intended to surface challenges of rural water supply in developing economies. It was done through intense literature review from publications released since early 1990s. Non-functionality rates and its causes, the institutional setups and practices in the sector havediscussed. To step up knowing underlying situations is very crucial. Therefore, elements of sustainability and their implication had assessed and discussed in this paper. Based on the review, efforts that have been made for the last three decades are concerned of sustainability issue but failed to achieve substantially. Still, a lot has to be done to bring sustainable services by involving all stakeholders and extending supports during post-implementation in order strengthen the ability of user to manage their systems.

Introduction

Background

Obviously, water is very essential to live and enhance development. Ancient civilization and modern settlements are certainly based on availability of water sources. Most cities in the world have established near to rivers, lakes or other water sources to that to assure their water security. However, in some circumstance following water a source for settlement is not feasible option, because some areas might have abundant water resources but unfavorable for livelihood and living. On the other hand,the nature of a livelihood in a particular community affects settlements to be made in water scarce areas. Searching for rain feed agricultural land, rural people have settled at top of mountains where the availability of water relatively problematic. This situation is commonly pronounced in Ethiopia too.

The rural settlement of Ethiopian is very scattered and very difficult to provide connected water supply system. Therefore, independent system for ever village is a mandatory unless for some exceptional cases. These make the effort of the country very challenging not to address the water supply coverage very quickly. The rural water supply coverage of Ethiopia was 14 % before 1990 and currently the government report show that it reached about 60%(MoWE, 2013). Recently, the national government with its partner organizations celebrated the achievement of the Millennium development goal 7c – to halve the population without water access by year 2015. This success story could be a springboard for future endeavors but not to relax now. Because as numerous number of water points implemented every year about 33% fail to give service. Therefore, the achievement can show to the actors that they can go more. On the contrary, the record of non-functioning schemes shows the gap of sustainability in the sector. Details will be discussed in chapter two and lets see few definitions of terms that are commonly used in the water supply and sanitation sector, and in this paper.

Definition of terms

Water supply coverage

Water supply coverage can be defined as the proportion of total population that access to improved water supply. Of course, it is clear to discuss about coverage but the term "improved water supply"could be clearly stated to avoid ambiguity because the presence of a water point in a community cannot guarantee the service coverage. Pipe water (house-connected, yard, public tap), boreholes, protected springs, protected dug wells, rainwater harvesting and bottled water are considered as improved water supply system (WHO/UNICEF, 2005). However, the service should satisfy the quantity required, standard quality and reasonable distance - accessible.

Non-functionality

The Oxford definition of Non-functionality is "*Not operating or in working order*". In the context of rural water supply schemes, non-functionality could imply scheme that stop giving service, schemes fail frequently, schemes with inadequate water, and scheme with bad water quality. Generally, a water supply scheme that lead user to go to alternative water sources called as non-functional scheme. Since this definition is not universal, this context will be consistently used in this research.

Sustainability

The definition of sustainability is becoming very subjective and varies from discipline to discipline. In fact, it is the most used and abused term in the development vocabulary (WaterAid, 2003). Therefore, common understanding needs to be set. In this paper sustainability implies the ability of water supply systems to give adequate quantity, quality, in accessible distance throughout the design life of ascheme and providing the capacity to extend by the user or local governments.

Provider and Producer

These two terms are usually used in the water supply sector reports, publications and programs. Sometimes they represent interchangeable and causing confusion (Katko and Hukka, 2015). Therefore, through my study and results presentations these terms used according to the definition of Ostrom (1990). She defined "providers" as a party that arrangesthe provision of the requirement of some thing, and produceris a party that directly involves on the physical implementation of things using supplied inputsby providers (Ostrom, 1990). To make very clear, if a government provide contraction materials, spare parts, and technology and the user put in place, repair and mange; the government is represent as provider and the user producer. Still, in some cases government could be found as producer if it tries to discharge implementation, repair, operation and maintenance of systems. The hierarchal relation of institutional framework, provision and production are well explained with illustration by Katko and Hukka (2015).

Institution

In my personal observation most people refer governmental offices, schools, churches and other public gatherings as institution. Moreover, in many studies institutional development mentioned as one of the important factor to bring sustainable services (Katko, 1991;Gine and Perez-Foguet, 2008; Eneas da Silva et al., 2013 and Spaling et al., 2014). Unless we have common understanding on the term the output of efforts may be questionable. Therefore, the definition employed for institution by Douglas C. North (1990) will be employed to assess the sustainability factors. Hedefined it as follow. "Institutions are rules of the game in a society". It built on the social norm, economic ability and political will (North, 1990, 3). In return it affects economy, politics and other social matters. No one is excluded and no one expected to be passive in building efficient institution. Every partner has own role and responsibility. The cumulative effects will determine success an institution. The analogy of football game (North, 1990) and the representation of the players in sanitation (Mattila, 2005) can show how institution is the sum of rules that designed for intended organizational objectives.

Rural water supply in developing economies

Efforts to improve the coverage of access to potable water supply and sanitation services have been increased in the past few decades and still the situations have not changed significantly in the Sub-Saharan countries. The water supply access increased from 49% in 1990 to 61% in 2010; and sanitation from 40% in 1990 to 49% in 2010 (WHO, 2012). The factors that seriously affect the coverage are population growth, climate change (Howard, 2010), the high rate of non-functionality,and lack of establishment of cost recovery system or its ineffectiveness (Harvey P., 2007 and 2008)

The National governments, partner organizations, and donors can hardly supply water supply services for their alarmingly increasing populations and the corresponding water demand in developing countries. Rather initiative of the user community and their contribution to the investment cost, and operation and maintenance is very important and determinant to ensure sustainability. Otherwise, it is a huge burden to the governments. It is resources consuming and unrealistic for the governments to take charge of the management duty of water supply schemes after implementation. As mentioned above, in average 40 % of the population waiting new services from the government. Therefore, the users need to be empowered and involved from the very beginning of a project to create concern and fully responsible for the post-implementation management and to give breath for the national government and partner organizations.

To make the user at the heart of projects a lot of approaches have been practice for the last three decades. Demand driven approach, which has been pronounced widely since the early 1990s, is still challenged by the conventional implementation approach. Lack of technical capacity and low literacy rate of the rural parts overwhelmed the active community involvement to strengthen the demand driven approach. On the other hand, the external agents like government and partner organizations, have exercising the ideology of supply driven approach at least partly.

The bottleneck is keeping the external agents in the position of service providers than producers. Government or partner organizations can no longer service producers to keep the operation and maintenance, and sources protection, because it became costly and non-achievable. Trying to act in the supply driven approach could levy a heavy burden on them while the end user suffers from lack of potable water supply and safe sanitation. Therefore, interests of community managed water supply and sanitation approaches, and community financing mechanisms should not overlooked for physical involvement of user in the implementation, rather it should be considered as a principal means of sharing burdens. It is easier for the community to take a protective measure in the system and consult the back-stoppers in the curative maintenance for technical support. Otherwise, the system faces tragedy of the commons (Ostrom, 1990). User benefit from water supply system as far as it is operational otherwise the go back to unprotected sources when fail to operate. This is actually against the objective of water supply.

As reported by WaterAid (2011), Taylor (2009), Harvey (2008)and many more literature non-functionalities of water schemes reach 35-50 percent, exceptionally in developing countries. However, the causes for extensive service breakdown are many (Laura R. Brunson, 2013) and vary from place to place, but lack of protective maintenance might exacerbate its severity. The implication of high non-functional rate is service coverage overshadowed and the efforts undermined. Thus, non-functionality attribute directly to the sustainability gap that reduced the total coverage by the same proportion (Harvey, 2008).

In any cases, the presence of high service breakdown rate could hinder the effort of addressing all. For example, in Ethiopia reducing functionality rate is one of the agenda of the Universal Assess Plan (UAP) and the Growth and Transformation Plan (GTP) to act against malfunctioning from 30% to 20% in addition to the new developments (UAP, 2011) and (GTP, 2010). The money, which allotted to cure non-functionality, could be reduced significantly if the communities were involved properlyduring implementation. However, improving the coverage of potable water supply and combating retarding effects have been addressed under different programs, but the impact is trivial and no one can be sure what will happen beyond the time horizon of the programs. In general term non-functionality is testing stakeholders in the water supply and sanitation.

Factors of non-functionality of rural water supply

Different researchers referred different elements as factors of sustainability. The most common factorsare social aspects, economic aspects, environmental, and institutional aspects (Katko, 1991;Bendahmane, 1993; Carter et.al, 1999; UN, 2007; Gine and Perez-Foguet, 2008; Montgomery etal., 2009; Eneas da Silva et al., 2013 andSpaling et al., 2014). Moreover, Carter et al. (1999) and Harvey (2007) insist to consider continuing support as important part of sustainability factor.

These elements are actually complicated. One element drives the other, thus it is difficult to explain separately. The main ideas that can be concluded from the literature mentioned above are the user and external agents need to take the most responsibility to keep system sustain. Moreover, among the factors social, economic, and institutional aspects are strongly tide together.

The stakeholders of water supply development are national government, local government, other partner organizations and the user community. The former three stakeholders have resources and technical ability to do projects, but they can't be absolute producers of systems. Whereas the user community may not have idea about the project and they are benefiting and live with a project. Here comes the need of thinking sustainability factors so that systems sustained. The social aspect is meant to contextualize projects in the manner it can be understandable, usable and respectable to a particular community norm and living style. The economic aspect emphasizethe user community to take part in contributing investment,operation and maintenance costs - for this the community needs to be convinced, social work has to be done. The institutional aspect focuses on rules of the game of the systems management (North, 1990).Therefore, the role of external agents seems very significant to involve and empower the user community in order to achieve the three elements of sustainability.

Environmental factor, of course, is somehow uncontrollable at projects level. Thus, it needs collaborative actions with other sectors like national environmental protection agencies, watershed management department, Agricultural and Industrial Ministries. However, during planning of water supply projects a due attention should be paid to select and implement appropriate technologies that fit the environment. From this aspect, wells dry up and yield reduction apparently are common problems in rural areas of the developing countries where climate change seen dominant.

The other very important element suggested by Carter et al. (1999) and Harvey (2007) is continuous support. Users, especially in the rural areas, are less exposed to a new management style and face shortage of economy to run systems. According to carter et al. (1999) and Harvey (2007), letting user with new system and strange management philosophy that they have never experienced will not produce any positive impact, though all other sustainability factors taken into account. The support is actually to help the user to reach the desired level as indicated in Figure 1.

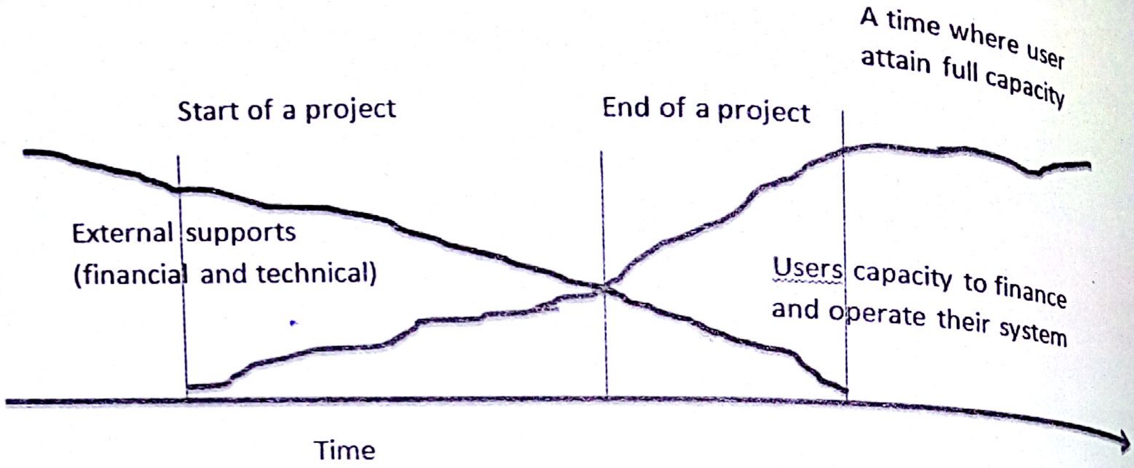


Figure 1: Roles of external support and user in producing a water system.

In general, the sustainability factors fall under the responsibility of the all stakeholders in different degrees. External agents are responsible in providing all requirement inputs for the implementation and management of water supply systems and the user community involve in the production of services right from start of projects. In other word, communities need to be the center of development of water supply and sanitation services.

After the International Drinking Water supply and Sanitation Decade (IDWSSD), the paradigm of supply driven shifted to participatory approaches to promote the involvement of user. Still, the concern is not changed and the problem also not solved. This situation has different feature from country to country. Accordingly Ethiopia implements water supply and sanitation through various approaches to reach and empower the rural people. One of the approaches that strive to go into communities deeper is called Community Managed Project (WFI, 2011).Thus, the research plan for the doctoral study is focusing on these implementation approaches particularly Community Managed Projects (CMP) approach.

Conclusion remarks

Based on the literature review the following points forwarded as conclusion remark.

Rural water supply and sanitation are the most active agenda of the developing countries for the last three decades,

The efforts of national governments and partner organizations are overshadowed by high rate of non-functionality. Currently, significant numbers of people are still without the services,

Social, economic and institutional aspects of sustainability should be elements solved together since one could be the result of the other,

Environmental factor is a factor of sustainability of water supply service but the solution should be interdisciplinary and universal. Still, environmental aspects at small scale should addressed adequately to protect sources from contamination, select appropriate and site specific technology that cope up existed challenges,

Wise and continuous support in addition to fulfilling the other sustainable factors is vital to enable users mange and sustain their system.

The technique of approaching user communities determine the success of built schemes in terms of sustainability and long lasting services. Therefore, every community should be approached in the way that they will have their own fingerprint in a system.

References

Bendahmane, D. B. & others., 1993. Lessons Learned in Water, Sanitation and Health: Thirteen Years of Experience in Developing Countries. *Water and Sanitation for Health Project and USAID.*

Carter, R. C., Tyrrel, S. F. ,Howsam, P., 1999. The impact and sustainability of community water supply and sanitation programmes in developing countries. *Water and Environment Journal, 13*(4): 292–296. Wiley Online Library.

Eneas da Silva, F. O., Heikkila, T., de Souza Filho, F. de A., Costa da Silva, D., 2013. Developing sustainable and replicable water supply systems in rural communities in Brazil. *International Journal of Water Resources Development*, *29*(4): 622–635. Taylor \& Francis.

Giné, R., Pérez-Foguet., 2008. Sustainability assessment of national rural water supply program in Tanzania.*Natural Resources Forum*, *32*(4): 327–342.

GTP. (2010). Growth and Transormation Plan, Ethiopia. Addis Ababa: Ministry of Finance and Economic Development.

Guy Howard, K. C. (2010). Securing 2020 vision for 2030: climate change and ensuring resilience in water and sanitation services. Journal of Water and Climate Change , 1 (1), 2-16.

Harvey, P. A. (2007). Cost determination and sustainable financing for rural water services in sub-Saharan Africa. Water Policy , 9, 373-391.D., 2013. Developing sustainable and replicable water supply systems in rural communities in Brazil. *International Journal of Water Resources Development*, *29*(4): 622–635. Taylor \& Francis.

Giné, R., Pérez-Foguet., 2008. Sustainability assessment of national rural water supply program in Tanzania.*Natural Resources Forum*, *32*(4): 327–342.

GTP. (2010). Growth and Transormation Plan, Ethiopia. Addis Ababa: Ministry of Finance and Economic Development.

Guy Howard, K. C. (2010). Securing 2020 vision for 2030: climate change and ensuring resilience in water and sanitation services. Journal of Water and Climate Change , 1 (1), 2-16.

Harvey, P. A. (2007). Cost determination and sustainable financing for rural water services in sub-Saharan Africa. Water Policy , 9, 373-391.

Harvey, P. A. (2008). Poverty Reduction Strategies opportunities and threats for sustainable rural water services in sub-Saharan Africa. Progress in Development Studies, 8 (1), 115-128.

Katko, T.S., 1991. *Paying for water in developing countries. Doctoral thesis*. Tampere University of Technology. Publication 74

Laura R. Brunson, L. W. (2013). In pursuit of sustainable water solutions in emerging regions: a Review paper. Journal of Water, Sanitation and Hygiene for Development , 489-499.

Mattila, H. (2005). *Appropriate Management of On-Site Sanitation.Doctoral thesis*. Tampere University of Technology. Publication 537.

Montgomery, M. A., Bartram, J., Elimelech, M., (2009). Increasing functional sustainability of water and sanitation supplies in rural sub-Saharan Africa. *Environmental Engineering Science*, *26*(5): 1017–1023. Mary Ann Liebert, Inc. 140 Huguenot Street, 3rd Floor New Rochelle, NY 10801 USA.

MoWE. (2013). Ethiopia Ministry of Wather and Energy. Retrieved 04 24, 2013, from Ethiopian Ministry of Water and Energy: http://www.mowr.gov.et/index.php?pagenum=0.1&ContentID=82

North, D. C. (1990). Institutions, institutional change and economic performance.Cambridge university press.

Ostrom, E. (1990). Governing the commons: The evolution of institutions for collective action. Cambridge university press.

Spaling, H., Brouwer, G. &Njoka, J., (2014). Factors affecting the sustainability of a community water supply project in Kenya. *Development in Practice*, *24*(7): 797–811. Taylor \& Francis.

Taylor, B. (2009). (2009), Addressing the Sustainability Crisis - Lessons from research on managing rural water projects. WaterAid.

UAP. (2011). REVISED RURAL WATER SUPPLY UAP. Addise Ababa: MOWE.

UN (United Nations), (2007). Indicators of sustainable development: Guidelines and methodologies. United Nations Publications.Department of Economic Development.

WaterAid. (2003). Indicators for the water sector: example from Malawi. WAterAid.

WaterAid. (2011, February 03). Retrieved February 23, 2012, from http://www.wateraid.org/documents/plugin_documents/sustainability_framework.pdf

WHO/UNICEF, (2005). Water for life: make it happen. http://www.who.int/water_sanitation_health/waterforlife.pdf?ua=1 accessed on May 25, 2015

WHO. (2012). Progress on Drinking-Water and Sanitation –2012 Update.

WIF. (2011). Federal Democratic Republic of Ethiopia: The WaSH Implementation Framework. Ministry of water and energy. Addis Ababa.

FLOOD HAZARD MAPPING, FORECASTING AND EARLY WARNING DEVELOPMENT IN THE BARO-AKOBO-SOBAT BASIN, GAMBELLA REGION OF ETHIOPIA AND SOUTH SUDAN ADJACENT REGIONS.

Eng. Chuol Biel Thoan[1], Dr. Yosif A. Ibrahim[2], Dr. Alemseged Tamiru[3]

[1] Hydrodynamic Modeler, Flood Preparedness and Early Warning System, Eastern Nile Technical Regional Office, P.O. Box 27173-1000 Addis Ababa, Ethiopia (chuolbiel@gmail.com), Mobile: +251917804794, Gambella, Ethiopia

[2] Senior Water Resources Planner for the Eastern Nile Technical Regional Office, P.O. Box 27173-1000 Addis Ababa, Ethiopia (YIbrahim@nilebasin.org)

[3] senior researcher, International water management institute, Addis Ababa, Ethiopia (alemsegedtamiru@yahoo.com)

Abstract

The consequences of flooding are complex and far-reaching. These consequences include direct damage to property and structures, as well as disruption of economic activity and displacement of affected population, with the attendant costs of evacuation and temporary accommodation. The first work undertaken includes the flood hazard mapping which is done along a 130 km reach of Baro River in the Gambella region of Ethiopia. River cross-section profiles are measured through topographic surveying at selected locations along the main river. The measured cross-sections are integrated with the floodplain digital elevation model through various GIS techniques. The flood model of the study area was calibrated for the 2007 major flood event by changing values of floodplain and channel Manning's roughness coefficient and then comparing simulated water level against measured water level at Itang gauge station. Model performance is evaluated by root mean square error (RMSE), bias, and average absolute percent error (AAPE). The RMSE for the calibration period was 0.119m which is only 1.998% of the average depth; the average bias error was -0.115; and the overall model average absolute percentage error was 1.967%. Values of all objective functions fall within reasonable limit suggesting satisfactory performance of the HEC-RAS model of the study area. Simulation was done for historic flood years of 1990, 2000, 2006, 2007 and 2010 using the calibrated flood model. Simulation results show that 30-85% of the total area of kebeles like Puldeng, Aleha, Waar, Adima, Itang Kir, Awany, Itang Town (Achua Kebele), Okura, wathgach, and Pilual was inundated by the five major flood events. Puldeng is the most affected Kebele in terms of inundation extent. Furthermore, tools were developed with the help of United State Geological survey (USGS) for flood mapping with globally available or locally produced topographic data. The resulting GIS Flood Tool (GFT) was developed to operate on digital elevation model (DEM) data to produce patterns of flood inundation corresponding to a river discharge or stage value specified by the user. The GFT was apply to mapping the inundation mapping for Baro-Akobo-Sobat basin and uses the DEM to derive stream networks and stream cross-sections. The Manning equation is then used for each streams to construct a stage-discharge relationship for each cross-section. Use of the stage-discharge relationship along with a specially processed Relative DEM allows for rapid mapping of the inundated extent. The resulting inundation patterns was used in conjunction with additional geographic information describing settlement patterns, transportation networks, land use and land cover to assess vulnerability to flood events and support preparedness planning. Comparison of the GFT results with inundation patterns produced using conventional hydraulic modeling approaches (HEC-RAS) and satellite remote sensing shows good correlation in many settings. Hydrologic Modeling (WMS) for the BAS basin uses ETA Weather forecast as an input for model setup. Work is also underway recently in cooperation with the word bank group to link GFT inundation patterns of the Baro-Akobo-Sobat basin with proxy hydrographs generated from satellite microwave observations at monitoring sites established by the Dartmouth Flood Observatory at the University of Colorado. This will include gauging stations at various areas in Ethiopia and South Sudan like Gambella, Itang, Nasir, Akobo, Pibor, and Hillet Doleib. Thus, finding of this study serves as an input to the planning and management of floodplain area of Gambella region and South Sudan adjacent regions of Eastern Equatoria, Jonglei, and Upper Nile to mitigate future probable disaster through appropriate intervention.

Key words: Floods, Hydraulic modeling, HEC-RAS, Hydrologic Modeling, ETA, BAS

Introduction

Flood forecasting and early warning is the provision of advanced warning of circumstances that are likely to cause potential risk of flooding to life and properties. The main purpose of the Eastern Nile Flood Monitoring program of flood forecasting and warning is to save life by allowing people to have early information and provide emergency services to prepare for flooding. The second purpose is to reduce the effects and damages from flooding.

Basically before doing any flood forecasts, the rainfall forecast was carried out in daily basis over the Eastern Nile region, giving emphasis on the flood prone areas over the region, by running ETA rainfall forecasting model. The ETA model outputs were utilized as an input to the flood forecasting model for each pilot flood-prone area. In addition, ETA rainfall forecasting model were compared with other regional and global numerical weather prediction models for the output verification based on 3 days lead-times forecast. This comparison was also helpful for the improvement and performance of ETA model. The Global and Regional numerical prediction model (NWP) models such as, Africa-Lam, ECMWF and NCEP|GFS were also explored and

Baro-Akobo-Sobat region is a flood prone area due to its flat topography. Thus, the overflow of major rivers of BAS (Baro, Gilo, Alwero and Akobo, and Pibor) causes to increase the water level and inundates the surrounding areas during the wet season. For these areas, Inundation of floodplains is mostly caused by lack of enough river conveyance to convey and therefore remove surface water excesses. The flood hazard mapping is done along a 130 km reach of Baro River in the Gambella region of Ethiopia and the Sobat River extending from sobat at mouth up to Hillet Doleib of south Sudan. In these floodplains, flood inundation causes damage to many infrastructures, properties, and crop jeopardizing the society's food security for most part of Gambella, Warrap, Northern Bahr el Ghazal, Western Unity, Upper Nile, Jonglei and parts of Eastern Central Equatorial states.

Objectives of the Study

The main purpose of this work is to execute a functional flood preparedness and forecasting and Early warning system for BAS by integrating GIS Flood Tool (GFT) with Geographic Information Systems (GIS) to map and compare the characteristics inundation with major historical floods events in the Baro-Akobo Basin with the general objective of "estimating characteristics of the flood wave and delineating flood zones in the BAS sub-basin by applying a hydrodynamic flood inundation model".

Methodology

In the development of BAS flood forecast model, ETA rainfall forecast is used as an input to the configured hydrologic model for Baro-Akobo-Sobat basin and the anticipated relative peak runoff during the forecast period were used as an input to hydrodynamic model component that was developed for Gambella Floodplain and the south Sudan plains areas with verification done

with mean daily gauge readings from Gambella and Itang Stations. Besides, Flow boundary condition is specified for the upstream boundary while normal depth is specified as the downstream boundary condition. The flood model of the study area was calibrated for the 2007 by changing values of floodplain and channel Manning's roughness coefficient and then comparing simulated water level against measured water level at Itang gauge station. A schematic of the conceptual design of the methodology for this study is shown in figure 3.1 and 3.2.

1. Data collection and field survey to characterize and provide input to terrain modeling and the use of Global mapper for extracting cross sections from the DEM.
2. Terrain modeling to develop a digital elevation model suitable for both extracting topographic data for the hydrodynamic model and for mapping the inundation that results from simulated hydraulic profiles;
3. Observed Flow Hydrograph analysis and hydraulic analysis and modeling to determine peak flow magnitudes and frequencies and associated hydraulic profiles;
4. Flood hazard mapping to represent inundated area, depth and velocity for the various peak flows.

Study area

The project area of BAS sub-basin, extending from the south-western part of Ethiopia to the South-eastern and central parts of southern Sudan which covers about 186,275 km2 with an estimated population of 3.6 million. The area provides a paradox: huge growth potential and natural resource endowment along with high incidence of poverty, natural resource degradation and overall low human development index. Potentials and endowments include: Hydropower generation, irrigation, river regulation-navigation, irrigated agriculture, fisheries, livestock, and (eco) tourism. A major challenge for developing the region is non-availability of adequate

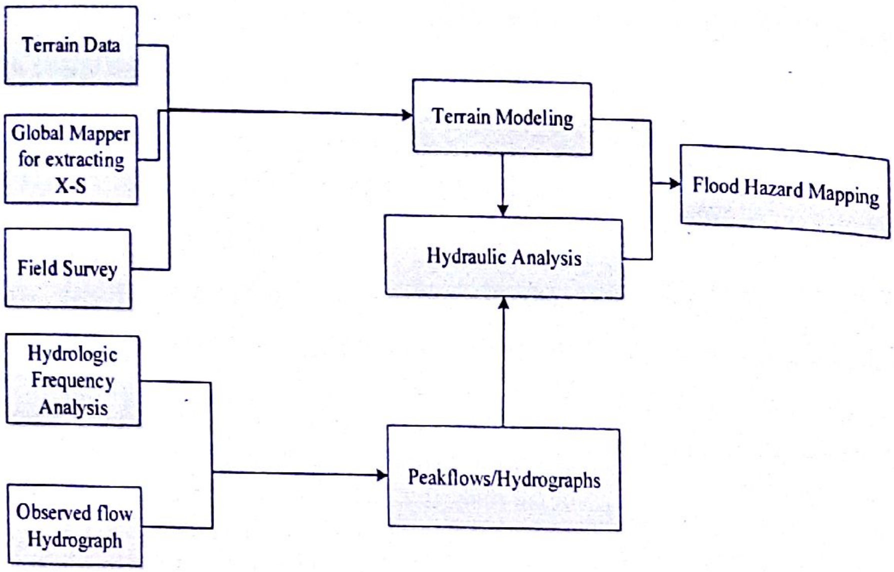


Figure 3-1: General approach for flood hazard mapping

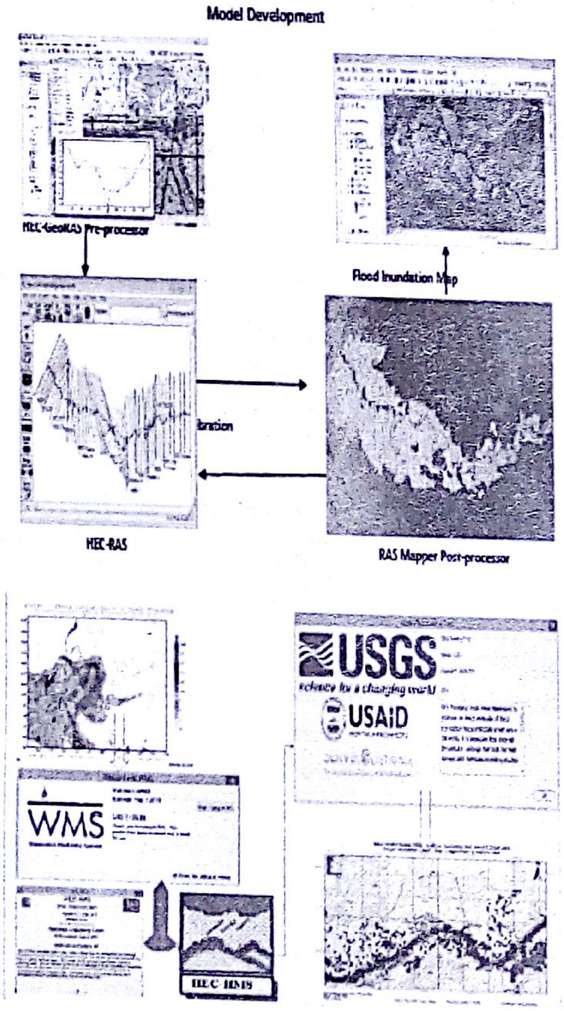
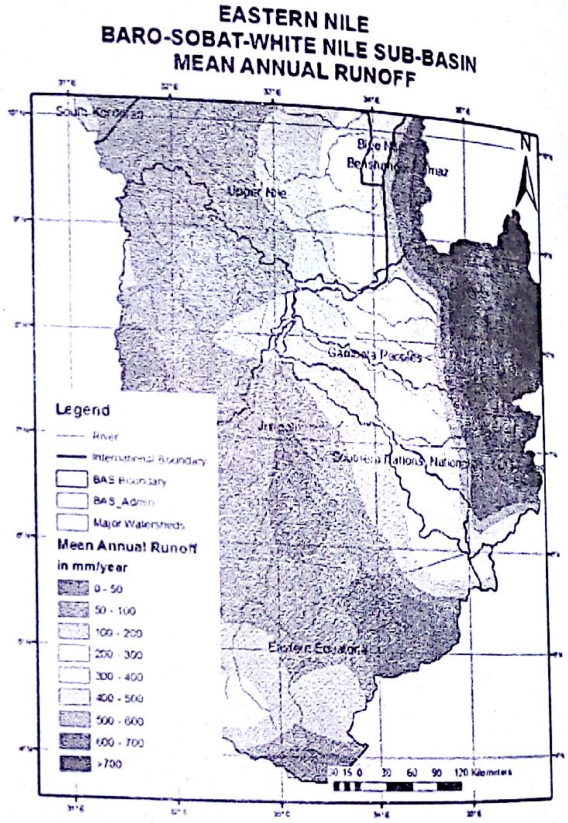


Figure 3-2: Illustration of HEC-RAS / HEC-GeoRAS model development and calibration procedure and BAS FEWS development

Results and discussions

This model had been calibrated using observed water level for one period which is a single year events (i.e.2007 flood year.) The channel geometry was kept constant for all simulations and the channel roughness was altered to match the model output with the recorded data. HEC-RAS and HEC-GeoRAS produce simulated water surfaces to GIS to produce inundation maps. Whereas HEC-GeoRAS maps inundation & Depth. The process is considered Iterative, thus Flood hazard have the following components (Inundation area, Depth of inundation, and Velocity).See figure 5-1 below.



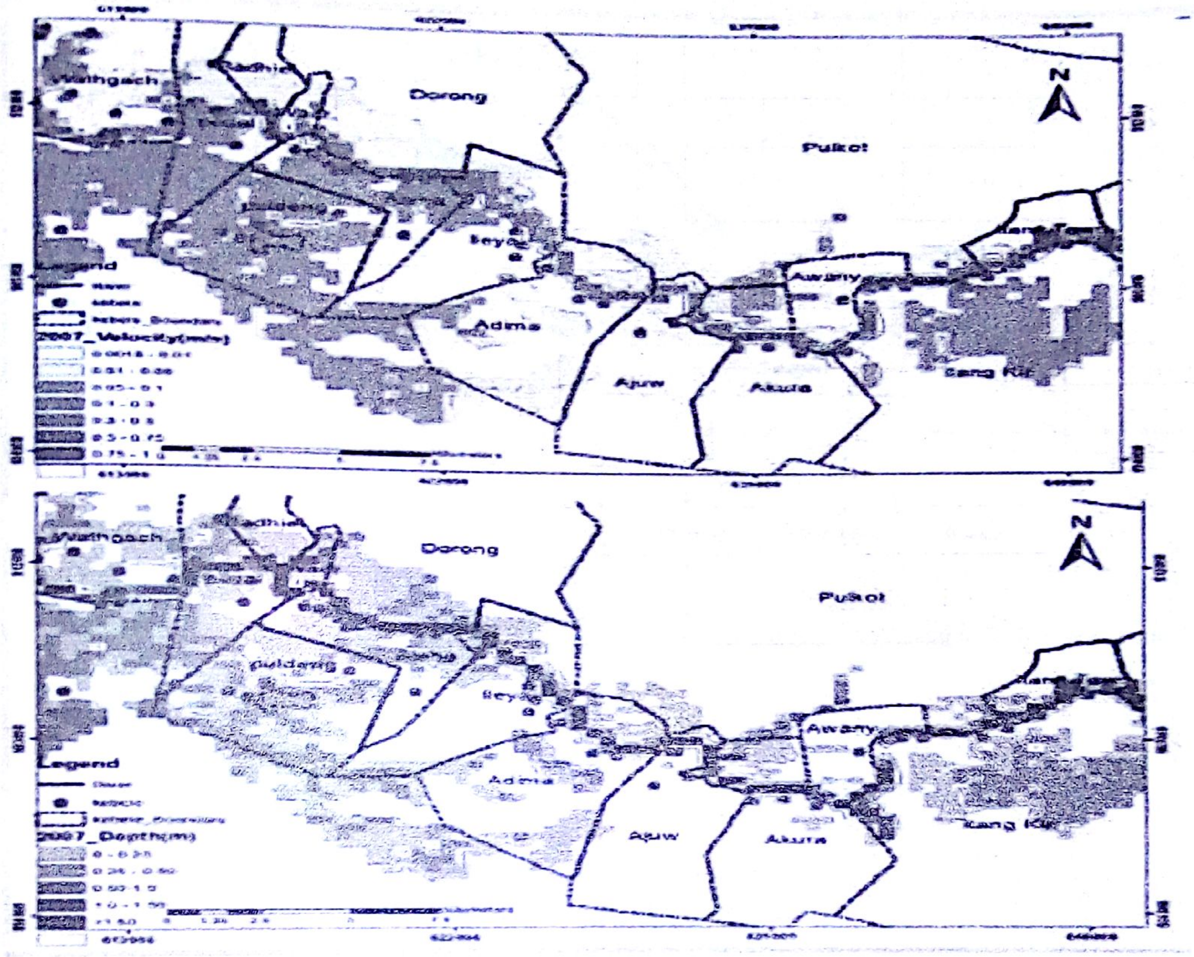


Figure 5-1: Development of inundation depth (blue gradients), flood extent (Red gradients) and Velocity Grid for 2007

Calibration

The period between 1st of July-31th August, 2007 is specified as a warming period to properly initialize the model. Calibration was conducted for the period of 1st of September-15th October, 2007. During calibration, simulated water levels were compared against observed water level data at Itang. The calibrated Manning's roughness (n) values are 0.038 and 0.06 for the channel and the floodplain, respectively.

Calibration results at Itang gages are shown in Figure 5-2. The solid line represents the modeled stage and the blue line with solid circles represents the observed Gage stage data at Itang. Comparison to observed data is appropriate after the first few days of modeled operations in order to eliminate the effects of initial conditions. The effect of accurate initial condition is minimized as a result of using a sufficiently long period for model warm-up but the effect is not fully eliminated. Over all, the model very well captured the temporal pattern of the observed water level at Itang and even captured the peak water level.

The scatter plot in Figure 5-3 shows the relation between simulated and observed water depths at Itang for the calibration period. A linear trend was fitted to the data points for comparison purpose. The results show a good conformity (R^2=0.9848) with observed values at the station used for calibration. However, the performance of the model in capturing spatial flood patterns should also be evaluated by comparing simulation results against flood extent map produced using satellite images capturing.

Objective evaluation of model performance is undertaken by using root mean square error (RMSE), bias, and average absolute percent error (AAPE) between the calculated and observed data for the period between 1st of September and 15th of October, 2007. Table 3-1 shows values of accuracy measures at Itang station. The average RMSE was 0.119m which can be considered too small since it is only 1.998% of the average depth. The average bias error was -0.115 which again indicate very good model performance. The overall model average absolute percentage error was 1.967% which also indicates a better performance evaluation. All errors falls within reasonable limit suggesting satisfactory performance.

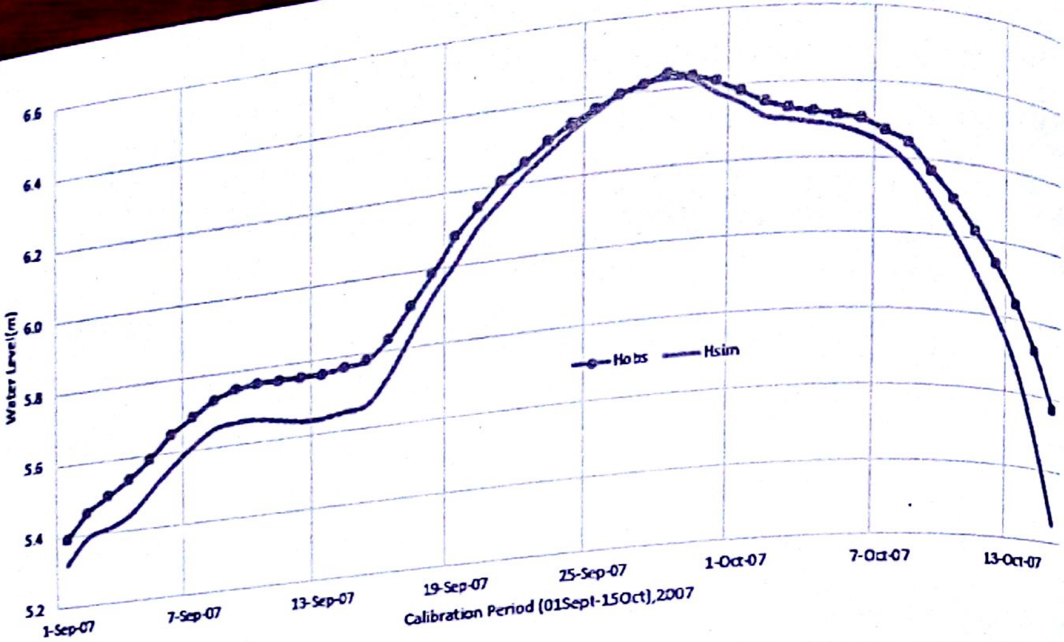


Figure 5-2: Simulated and observed water level for 1st of September 2007 to 15th of October, 2007 at Itang Gage station

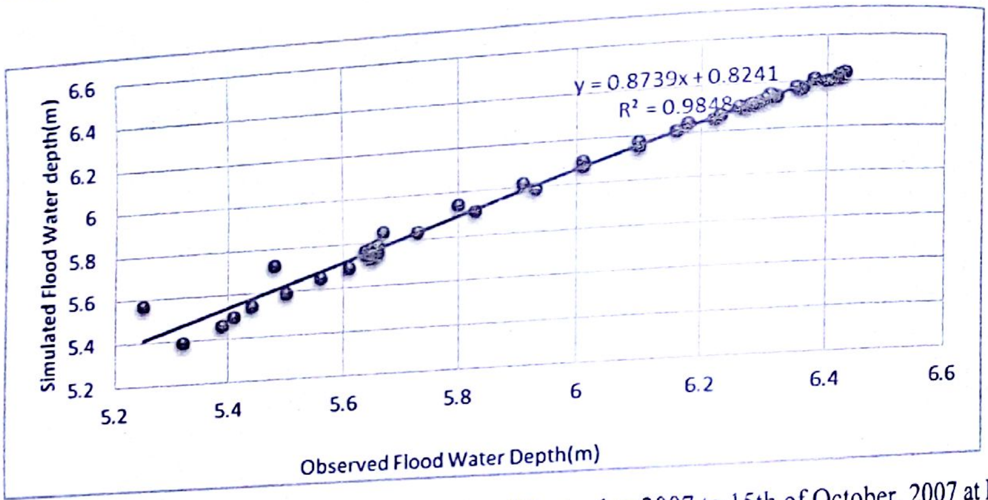


Figure 5-3: Scatter plot of simulated and observed water depth at Itang for 1st of September 2007 to 15th of October, 2007 at Itang Gage.

Table 5-1: Model performance measures as calculated for 1st of September to 15th of October 2007 at Itang Gage

Parameter/Gage	Itang Gauging Station
RMSE(m)	0.118828
Bias (m)	-0.11467
AAPE	0.019671
RMSE/Avg.cross section Depth (%)	1.997998

Simulation of Historic Events

An unsteady flow routing model was used to simulate the hydraulics of the 1st of September to 15th of October, 2010, 2006, 2000, and 1990 flood in the Baro River basin system. The model was setup and specified an initial condition for the period 1st of July to 1st of September of each year for Baro River at Itang. Flow hydrographs were used as upstream boundary conditions, whereas normal depth was used as downstream boundary conditions at the confluence of the khor Jiokow and the Baro River and by lowering the elevation of the downstream end cross-section to take into account the backwater effect.

An analysis of the flooded area was assessed by overlaying flood extent the Kebele polygon map in ArcGIS for all flood events. The main purpose is to see the degree of severity of flood in different Kebele of Itang Woreda. Figure 4-5 shows the percentage of area covered in each Kebele during the historic simulation periods.

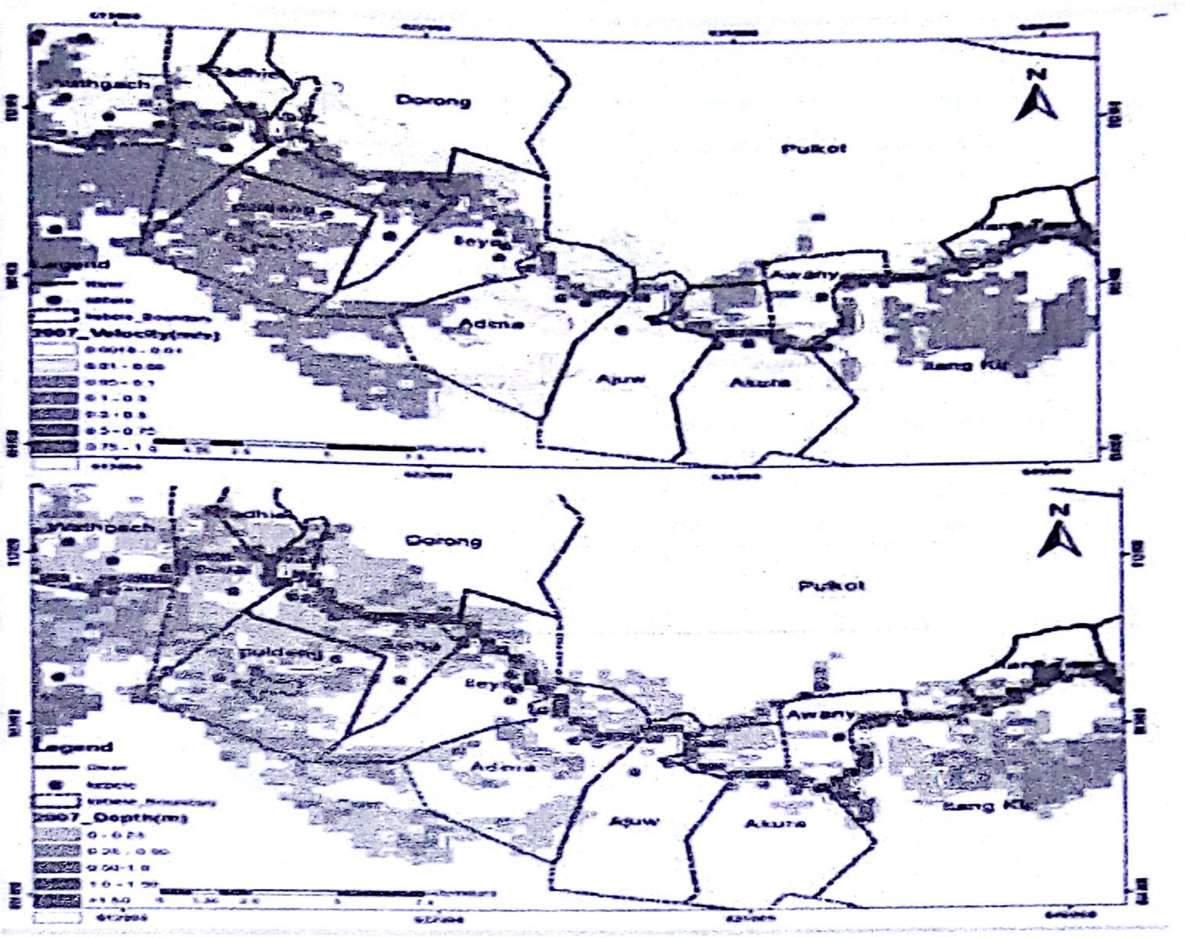


Figure 5-1: Development of inundation depth (blue gradients), flood extent (Red gradients) and Velocity Grid for 2007

Calibration

The period between 1st of July-31th August, 2007 is specified as a warming period to properly initialize the model. Calibration was conducted for the period of 1st of September-15th October, 2007. During calibration, simulated water levels were compared against observed water level data at Itang. The calibrated Manning's roughness (n) values are 0.038 and 0.06 for the channel and the floodplain, respectively.

Calibration results at Itang gages are shown in Figure 5-2. The solid line represents the modeled stage and the blue line with solid circles represents the observed Gage stage data at Itang. Comparison to observed data is appropriate after the first few days of modeled operations in order to eliminate the effects of initial conditions. The effect of accurate initial condition is minimized as a result of using a sufficiently long period for model warm-up but the effect is not fully eliminated. Over all, the model very well captured the temporal pattern of the observed water level at Itang and even captured the peak water level.

The scatter plot in Figure 5-3 shows the relation between simulated and observed water depths at Itang for the calibration period. A linear trend was fitted to the data points for comparison purpose. The results show a good conformity (R^2=0.9848) with observed values at the station used for calibration. However, the performance of the model in capturing spatial flood patterns should also be evaluated by comparing simulation results against flood extent map produced using satellite images capturing.

Objective evaluation of model performance is undertaken by using root mean square error (RMSE), bias, and average absolute percent error (AAPE) between the calculated and observed data for the period between 1st of September and 15th of October, 2007. Table 3-1 shows values of accuracy measures at Itang station. The average RMSE was 0.119m which can be considered too small since it is only 1.998% of the average depth. The average bias error was -0.115 which again indicate very good model performance. The overall model average absolute percentage error was 1.967% which also indicates a better performance evaluation. All errors falls within reasonable limit suggesting satisfactory performance.

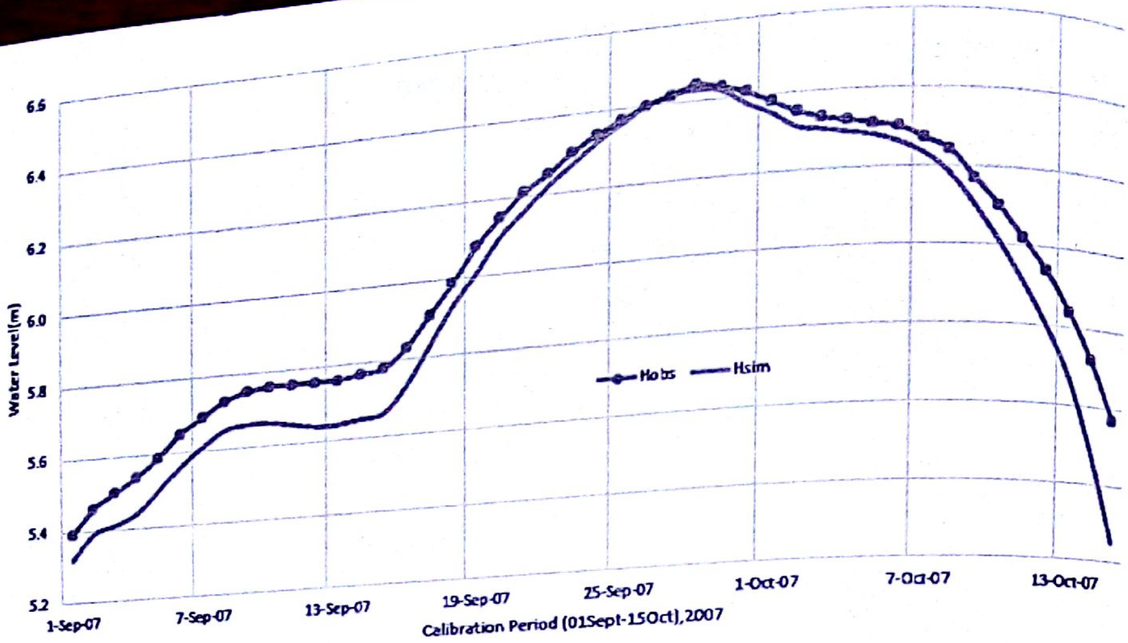


Figure 5-2: Simulated and observed water level for 1st of September 2007 to 15th of October, 2007 at Itang Gage station

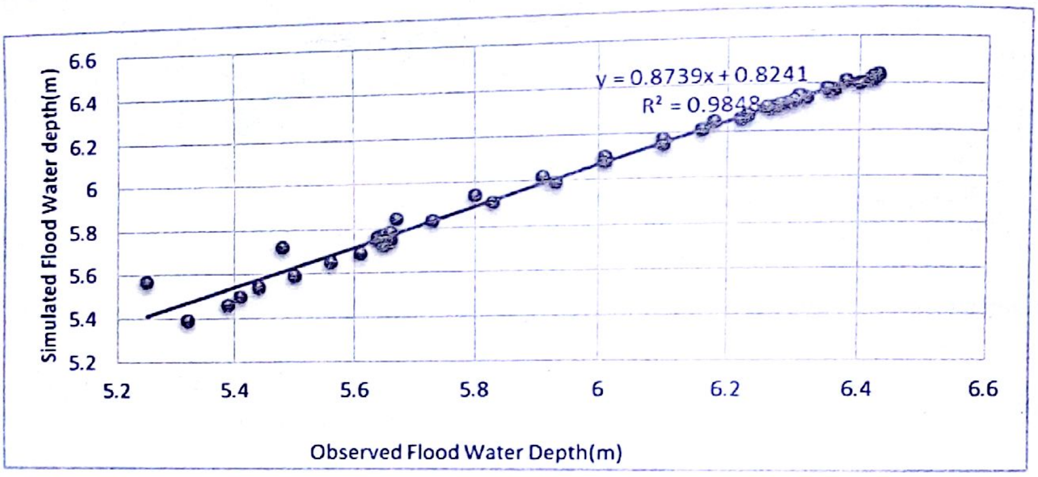


Figure 5-3: Scatter plot of simulated and observed water depth at Itang for 1st of September 2007 to 15th of October, 2007 at Itang Gage.

Table 5-1: Model performance measures as calculated for 1st of September to 15th of October 2007 at Itang Gage

Parameter/Gage	Itang Gauging Station
RMSE(m)	0.118828
Bias (m)	-0.11467
AAPE	0.019671
RMSE/Avg.cross section Depth (%)	1.997998

Simulation of Historic Events

An unsteady flow routing model was used to simulate the hydraulics of the 1st of September to 15th of October, 2010, 2006, 2000, and 1990 flood in the Baro River basin system. The model was setup and specified an initial condition for the period 1st of July to 1st of September of each year for Baro River at Itang. Flow hydrographs were used as upstream boundary conditions, whereas normal depth was used as downstream boundary conditions at the confluence of the khor Jiokow and the Baro River and by lowering the elevation of the downstream end cross-section to take into account the backwater effect.

An analysis of the flooded area was assessed by overlaying flood extent the Kebele polygon map in ArcGIS for all flood events. The main purpose is to see the degree of severity of flood in different Kebele of Itang Woreda. Figure 4-5 shows the percentage of area covered in each Kebele during the historic simulation periods.

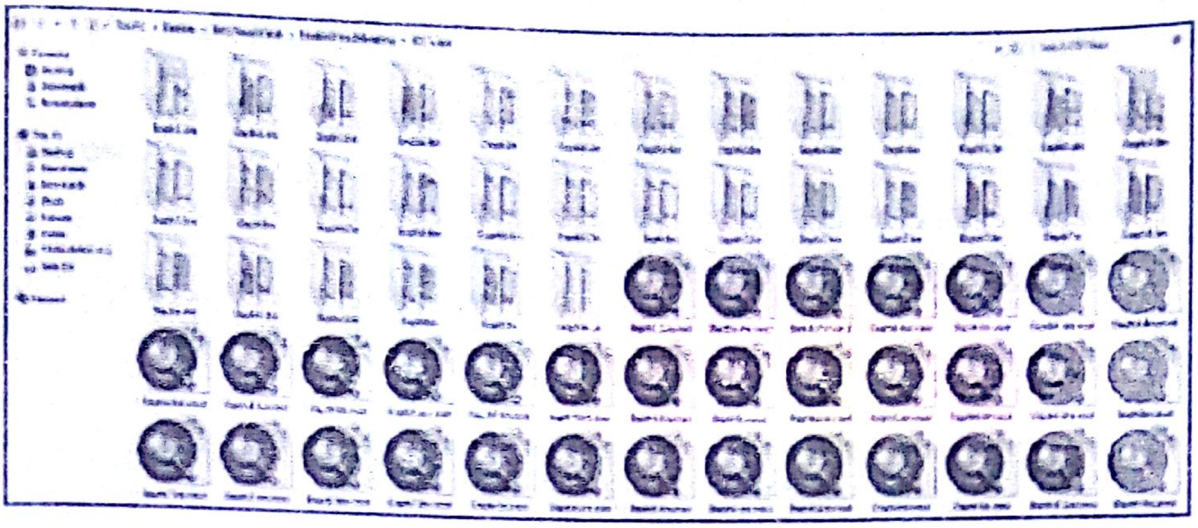


Fig-ure 5-8 Data archiving and flood Maps Library for BAS Areas

Flood inundation Maps were developed for each localities or communities in both Gambella and South Sudan flood prone areas

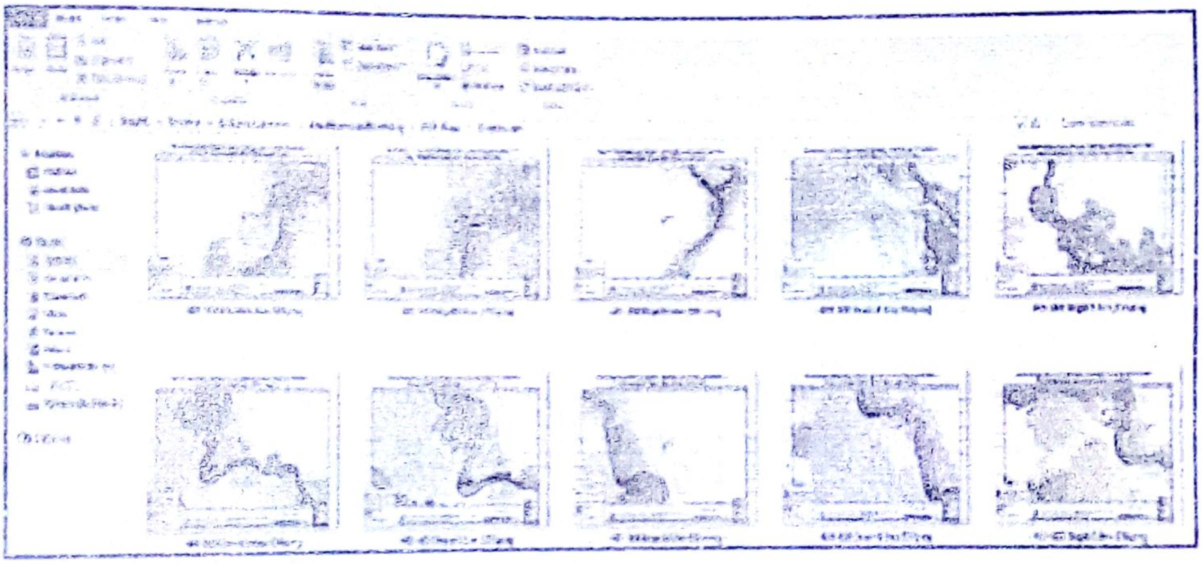


Figure 5-9 Flood inundation maps in Gambella and South Sudan flood-prone areas

River mean daily gauge readings are sent through mobile messages daily and used as a mean to see the variation of this year (2014) flood level as compared to the historical flood recorded. There was also field visit to arrange and handover the mobile apparatus bought by ENTRO to gauge reader personnel at Gambella and Itang. Figures below show the daily forecast and river levels monitoring in BAS areas, the field visits, and the flood web application.

Conclusion and the way forwards

Finding of this study serves as an input to the planning and management of floodplain area of Gambella region and South Sudan adjacent regions of Eastern Equatoria, Jonglei, and Upper Nile to mitigate future probable disaster through appropriate intervention.

Local communities have good awareness about the recurrent flood challenges they faced, but need regular updates of flood risks, integrated impacts and its potential damages need be addressed and how to protect themselves and their properties from such recurrent flood risks.

In BAS river systems, some of the challenges are lack of topographic data, detail topographic survey is preferable and need to be conducted ; lake of hydro-met data from key gauging stations (need of establishing additional new gauging stations) where some structures are planned and especially in Baro, Gilo, Alwero, Akobo and Sobat River; gaps in terms of capacity in Flood Forecasting and Early Warning systems; and of course the current conflict in South Sudan is a big challenge to collect appropriate data, Need of Upgrading of key flow measurement stations, need of addressing the environmental benefit aspects of

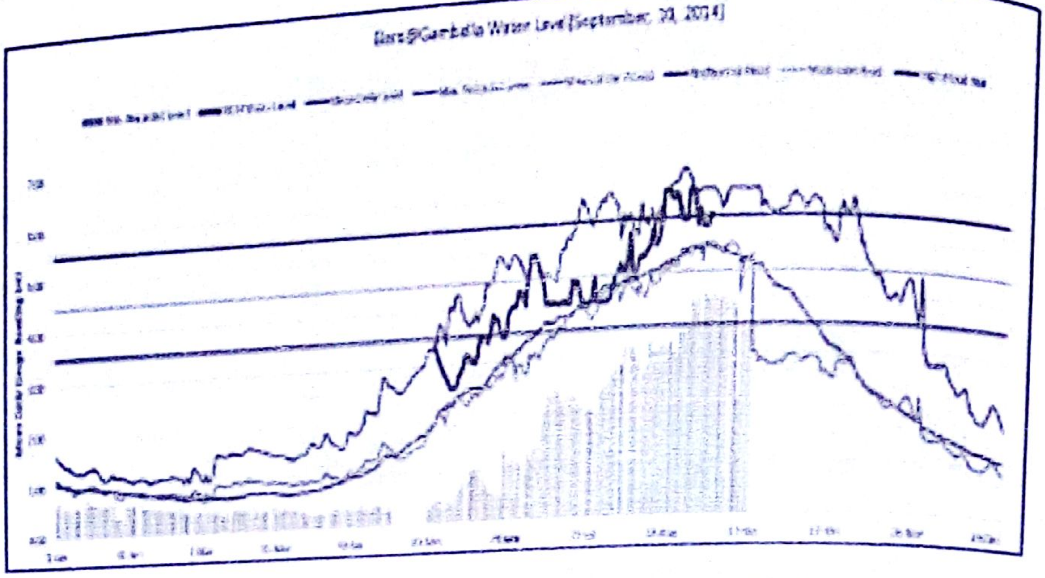


Figure 5-10: Gambella Gauging station daily flows compared with the historical records

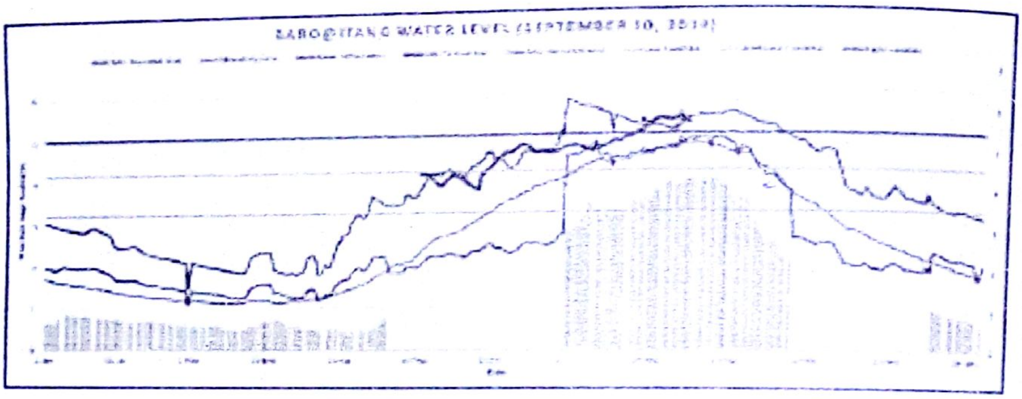


Figure 5-11: Itang Gauging station daily flows compared with the historical records

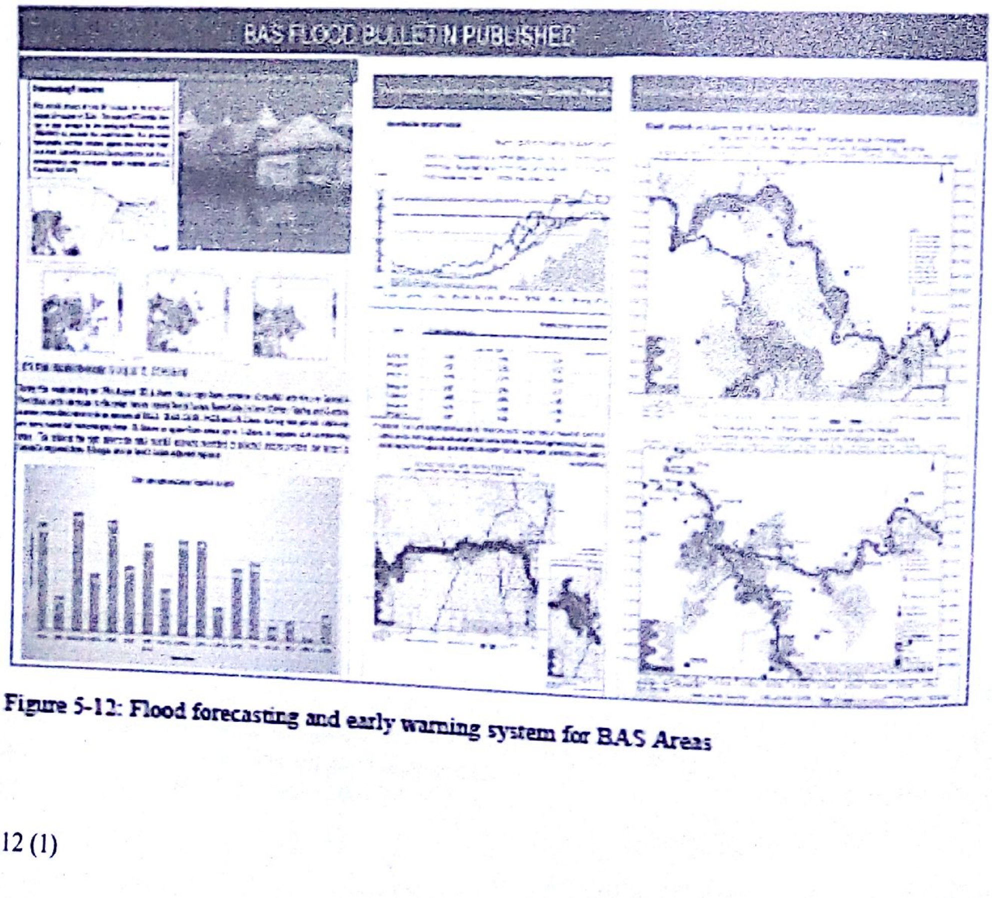


Figure 5-12: Flood forecasting and early warning system for BAS Areas

Figure 5-13: Gambella and Itang gauging station readers with the Author during handover of mobiles bought by ENTRO

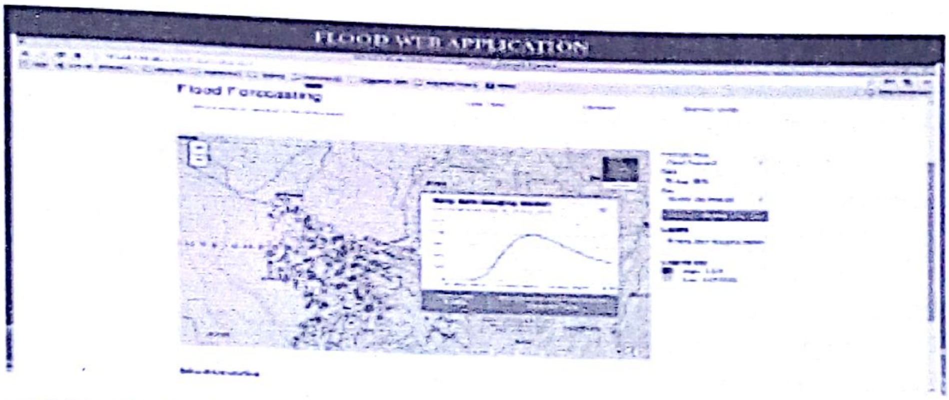


Figure 5-14: Flood web application in BAS system, a prototype -Itang

flooding in the EN is highly recommended, The need of addressing flash flood issues should also be as part of configured forecasting models. For instance, in South Sudan many places (Bahr el Ghazal and Bahr el Jabel) are affected by floods which need to be taken as part of EN Flood Monitoring program during each flood forecasting season.

References

Flood Risk Mapping in Pilot Areas of Ethiopia and Sudan http://www.riverside.com/

Riverside & UNESCO CWR (2010), Final Report, Flood Risk Mapping Consultancy for Pilot Areas in Sudan.

http://www.nilebasin.org/newentro/eastern-nile-flood-preparedness-and-early-warning-project

GIS Flood Tool Manual , ENTRO, 2012

Acrement, G.J., Schneider, V.R., (1984). Guide for selecting Manning's roughness coefficients for natural channels and floodplains. Report No. FHWA-TS-84-204. Federal Highways Administration US Department of Transportation, Washington.

Awal, R. (2003). Floodplain Analysis and Risk Assessment of Lakhandei River. Nepal.

Badilla Roy. A, (2008), Flood Modeling in Pasig-Marikina River Basin, ITC Enschede, The Netherlands

DPFSA, G. R. (2010). Gambella Regional Disaster prevention and food security Agency. Gambella regional state, Ethiopia.

Haile, A.T (2005). Integrating hydrodynamic models and high Resolution DEM LIDAR for Flood modeling .ITC, Enschede, The Netherlands

Haile, A.T., Rientjes, T.H.M (2005). Effects of LIDAR DEM resolution in flood modeling: a model sensitivity study for the city of Tegucigalpa, Honduras. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 36 (3), 168–173.

HEC, Hydrologic Engineering Center (2010). HEC-GeoRAS, GIS Tools for Support of HEC-RAS using ArcGIS® User's Manual Version 4.2. Davis, California, USA

HEC, Hydrologic Engineering Center (2010). HEC-RAS, River Analysis System, Version 4.1.). Davis, California, USA.

Tarekegn T.H. Haile, A.T, Rientjes, T.H, Reggiani, Dinand, A. (2010). Assessment of an ASTER-generated DEM for 2D hydrodynamic flood modeling; International Journal of Applied Earth Observation and Geo-information 12 (2010) 457–465

UNDP (2004). Reducing disaster risk: A challenge for development United Nations Development Programme, Bureau for Crisis Prevention and Recovery, New York, 146 pp.

Assessment of Urban Water Supply and Sanitation: The Case of Bedesa Town, Damot Woyde Woreda of Wolaita Zone, Southern Ethiopia

Ermias Mekonnen[1], Brook Abate[2] and Kannan Narayanan[2]

[1]*College of Agriculture, Wolaita Sodo University; E-mail: erumoke@yahoo.com; P.O.Box: 138, Telephone No. +251 9 25 30 90 88, Wolaita Sodo, Ethiopia*

[2]*School of Bio-systems and Environmental Engineering, Hawassa University; P.O.B. 05, Hawassa, Ethiopia*

ABSTRACT

This study was conducted in Bedesa town, Wolaita zone, southern Ethiopia to assess the water supply and sanitation situation of the town. For this study, 195 households were selected by using systematic random sampling technique. Both primary and secondary data sources were used in this study. For primary data collection, household surveys, key informant interview, focus group discussion and personal observation were used as tools to collect the necessary information. For secondary data collection, document review was used to collect valuable information. The existing water distribution system was analyzed using engineering software, EPANET-2. The data from the respondents were analyzed using descriptive statistical techniques and explanation building. Accordingly, one way ANOVA was employed to see the statistical significances of the variables at 5% significant level; correlation was also used to observe associations of the variables. The findings revealed that the average per capita domestic water consumption of the town was found to be 9.6 l/c/d for the base year (2014) which only satisfies 48% of the minimum urban water consumption value set by WHO as a basic need (20 l/c/d) without considering the distance travelled to fetch water. The result of water quality test revealed that average values for all selected physico-chemical water quality parameters were found within the acceptable limits of WHO and Ethiopian water quality standards. But, the mean value of temperature for source, reservoir, pipeline and household container were beyond the recommended WHO value (<15 °C); the laboratory result of bacteriological water quality for all sampling sites were also in agreement to the WHO and ES of potable water quality. Similarly, sanitation situation in the town was not good and encouraging. Lack of private sanitary pit, poor hand washing practice, lack of communal land fill, improper handling and disposal of wastes and lack of drainage ditch were identified as the major factors responsible for poor sanitation situation of the town. The major coping strategies for the challenges of Bedesa town water supply are synchronizing different water sources, conserving water sources, demand management, demand oriented supply, participating different actors, mobilizing financial resources, and establishing organizational structure with skilled staff and equipping it with material facilities. Likewise, the strategies for managing sanitation challenges include constructing communal land fill, constructing drainage ditch, awareness creation on hand washing after defecation and waste handling and disposal method, and integrating water supply and sanitation sectors.

Key Words: Water supply, water quality, sanitation, hygiene, water demand, distribution: Bedesa.

Introduction

Water supply and sanitation are two of the most important sectors of development. Development of community water supply and sanitation results in improved social and economic conditions and improved health. The benefits of improved water supply and sanitation are many, including prevention of disease, improved basic health care, better nutrition, increased access to institutions such as health centers and schools, improved water quality, increased quantity of and access to water, reduction in time and effort required for water collection, promotion of economic activity, strengthening of community organization, improvements in housing, and ultimately improved quality of life (Andrea, 2002).

Inadequate access to clean drinking water directly or indirectly affects health. According to WHO, more than 80% of diseases in the world are attributed due to unsafe drinking water or to inadequate sanitation practices (WHO, 2003a). Global statistics estimate that currently the world is not on track to meet the MDG sanitation target, and 2.5 billion people still lack access to improved sanitation, including 1.2 billion who have no facilities at all particularly in Sub-Saharan Africa and Southern Asia (WHO/UNICEF, 2006).

Bedesa town has been experiencing the problem of adequate safe water supply and basic sanitation.

The dwellers of this town are at the forefront to be affected by the problem of poor access to potable water and basic sanitation. In this town, the demand for water in terms of quantity and quality is fast outpacing its availability for consumption, and the supply of domestic water is seriously constrained by the rapid population growth in and around the town. As a result, both governmental and non-governmental organizations made their efforts to improve the water supply and sanitation situation of Bedesa town. However, there is still a significant information gap on the water consumption pattern of households, water supply coverage, accessibility, quality, future water demand forecasting, and sanitation coverage of the town. In this town, not adequate research is yet carried out to solve the water and sanitation related problems affecting the residents of the town. Therefore, the researcher initiated to conduct this study in this particular area.

Objective of the Study

The general objective of this study is to assess the water supply and sanitation situations and forecast the future domestic water demand of Bedesa town by 2024.

Materials and Methods

Description of the Study Area

Bedesa town, the capital of Damot Woyde Woreda, is found in Wolaita Zone, Southern Nations, Nationalities and Peoples' Regional State. Bedesa is geographically located approximately in latitudes of 6°51′30″ and 6°54′0′ ′N, and longitudes of 37°54′30″ and 37°57′0″ E. The study area experiences average daily temperature of 16 °C to 31 °C. The average annual rainfall of the area ranges between 1001 and 1400 mm.

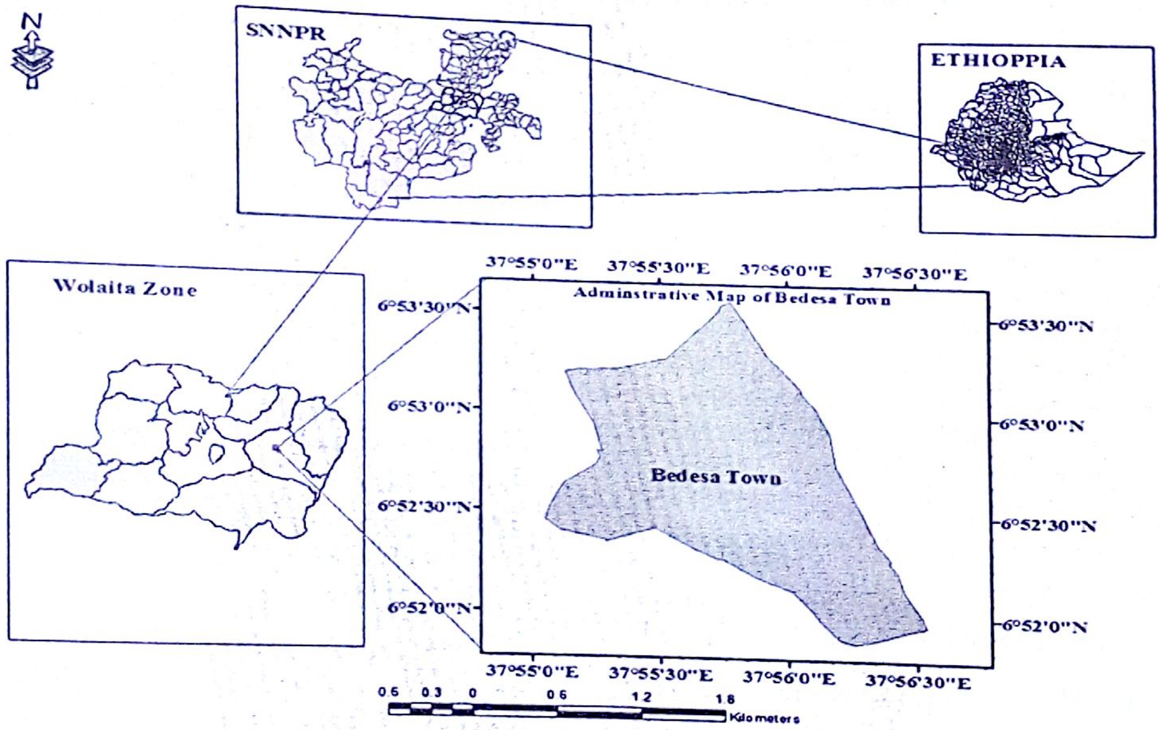


Figure 1. Location Map of the Study Area

Data Sources and Collection

In order to achieve the stated objectives of the study, a combination of both primary and secondary data sources were used.

The primary data were gathered through structured questionnaires administered to the households (water consumers), personal observation of water supply and sanitation schemes and focus group discussion which enabled the researcher to address the opinion of the community towards access to potable water and basic sanitation and its impact on their daily activities. Besides, primary data were collected via key informant interview with people from different offices and community with different responsibility, knowledge and experience about the town's potable water and sanitation coverage, the balance between demand and supply of water, major problems facing the provision of potable water and sanitation services, level of community awareness and participation in the provision of these services. The secondary data were gathered from the available data sources such as census and survey reports, journals, internet as well as other published and unpublished documents.

Sampling Technique and Sample Size

In this study, both probability and non-probability sampling techniques were employed to draw the sample households, focus group discussants and key informants. Accordingly, 195 households were selected by systematic random sampling technique from both kebeles of the town. Finally, Key informants and focus group discussants were selected purposively.

Water Quality Analysis

To examine the physico-chemical quality of drinking water, representative samples were taken in triplicate from the current source of the town's water supply i.e. spring water, the existing service reservoir i.e. Rs-1, from pipeline, and representative samples from respective end users (household containers) of each kebele. For bacteriological water quality test, the samples were taken in triplicate from the above mentioned sources for total coliform and faecal coliform tests.

Data Analysis

Statistical techniques were used to analyze the data obtained from the survey respondents. The computer software application that is Statistical Package for the Social Science (SPSS) was used to analyze the data obtained from household survey. The field survey data for distribution system was evaluated by using the engineering software called EPANET-2. Furthermore, correlation was employed to see the relation between household size and per capita water consumption as well as household income level and per capita water consumption. Moreover, ANOVA was used to determine the significant differences in the mean values of the water quality parameters at the various sampling sites.

Results and Discussion

Existing Water Supply System of Bedesa Town

Domestic Water Supply Coverage

During household survey, data were collected on the quantity of water required and consumed by the respondents. As presented in Table 1, the survey result revealed that the average quantity of water required by the respondents was found to be 25.34 l/c/d; the finding of this study also revealed that the average amount of water consumed by the respondents was found to be 9.6 l/c/d. According to WHO (2008), the minimum quantity of domestic water required in urban areas of developing country is taken as 20 l/c/day. Regarding to this value, the domestic water supply of Bedesa town only satisfies 48% of the standard value without considering the distance travelled to collect water.

Table 1. The per capita water demand and consumption (l/c/d) by the sample households

	Per Capita Water Demand (l/c/d)	Per Capita Water Consumption (l/c/d)
Mean	25.34	9.6
Maximum	40	16.5
Minimum	10	1.67
Range	30	14.83
Variance	39.165	9.65
Standard Deviation	6.256	3.106

The findings also revealed that water shortages are critical in the months of December to March. Majority of the respondents said that the amount of water supply does not meet their need throughout the year. This is true as the researcher during his field observation saw long queues of people, mostly women and children, searching for water in public taps and improved spring. This finding corresponds to the FRN (2000) estimation that currently only about 50% of the urban and 20% of the semi-urban population have access to reliable water supply of acceptable quality.On the issue of average distance travelled to collect potable water, 51.8% of the respondents said that the distance to their source of potable water is less than 100m, 34.9% said that it is between 101 and 500 m, 7.7% between 501 and 1000 m, while 5.6% said it is above 1000 m. According to WHO (2008), the minimum quantity of domestic water required in urban areas of developing country is taken as 20 l/c/day within the radius of 0.5km. But, in the study area, for 13.3% of the respondents, water was not accessible.

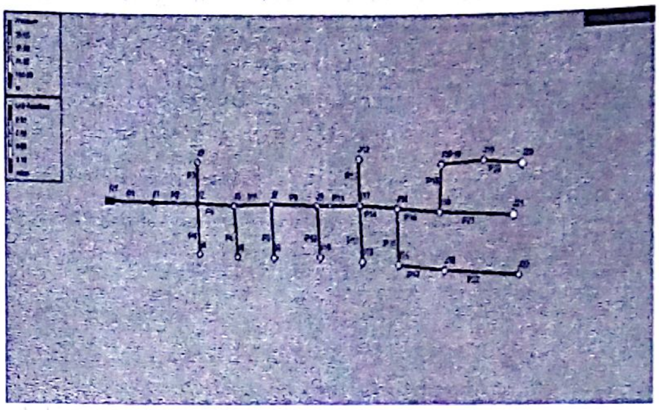
The normal maintenance period for a water facility as recommended by WUP (2003) is 2 to 3 days. The long maintenance period observed to be in excess of 2 months during the study period might contribute to the non-reliability of water services in the study area.

The correlation result of the association of the households' per capita water consumption with household's monthly income shows that there is positive relationship between per capita water consumption and household income with correlation value of 0.518. But, the correlation result of the association of the households' per capita water consumption with family size shows that per capita water consumption and family size are negatively related with correlation value of -0.504.

Water Distribution Network

In Bedesa town, the source of piped water supply was found to be one spring stream. Water from the stream is transported by a gravity pipeline to the main distribution tank in the town before it is distributed to consumers. Fig 2 shows the distribution network map of the town water supply system. The purpose of a water distribution network is to provide system users the amount of water demanded and to supply it with sufficient pressure. The Ethiopian guideline criteria for the minimum and maximum operating pressure value in the distribution network are 15m and 70m respectively (MoWR, 2006). The guide line further states that water velocity shall be maintained at less than 2 m/sec and a minimum of 0.6m/sec, but for looped systems there will be pipelines with section of zero velocity. The low pressure nodes are normally those nodes which are located relatively at high elevations and far from the supply points.

Figure 2. Water Distribution Network Map of Bedesa Town



Water Demand Projection

The total water demand of the town was determined by summing up the adjusted domes.tic water demand and Non domestic water demand as shown in Table 2. Thus, the currently available water production and the projected future water demand indicate the need for the development of additional water sources to satisfy the 736.54m^3/day water demand of Bedesa town for coming 10 years period. Therefore, searching for new water sources and increasing the water supply efficiency seem to be expected actions of the stakeholders of the sector.

Table 2. Water demand projections of Bedesa town by category till 2024

Year	2014	2015	2018	2021	2024
Population	7702	8010	9010	10,000	11,183
Average per Capita Domestic Demand (l/c/d)	34.91	35.43	37.05	38.76	40.53
Climatic Adjustment Factor	1	1	1	1	1
Socio-economic Adjustment factor	1	1	1	1	1
Adjusted Average Domestic Demand (l/c/d)	34.91	35.43	37.05	38.76	40.53
Adjusted Domestic Water Demand (m^3/d)	268.88	283.79	333.82	387.60	453.25
Percentage of non domestic demand (%)	30	30	30	30	30
Non domestic water demand(m^3/d)	80.66	85.14	100.15	116.28	135.98
Total Water Demand (m^3/d)	349.54	368.93	433.97	503.88	589.23
Percentage of loss as production (%)	25	25	25	25	25
Non revenue water demand (m^3/day)	87.39	92.23	108.50	125.97	147.31
Projected Water Demand (m^3/day)	436.93	461.16	542.47	629.85	736.54

Water Quality Analysis

Physico-Chemical Quality Analysis

Table 3. Laboratory results of physico-chemical water quality parameters

Physico-Chemical parameters	Source	Reservoir	Pipeline-1	Pipeline-2	Household Container1	Household Container2	WHO standard	Ethiopian Standard
Temperature (°C)	25.87	25	25.67	26.33	25	25	<15	-
Turbidity (NTU)	2.01	1.06	0.93	1.31	0.94	0.96	5	7
PH (pH)	6.87	6.77	6.6	6.7	7.01	7.13	6.5-8.5	6.5-8.5
EC (µS/cm)	145.67	142	141.67	148.33	161.67	162	1000	-
TDS (mg/l)	146	131	139	134.67	134	134.33	1000	1000
Total Hardness as $CaCO_3$ (mg/l)	124.67	128	127.33	121	127.67	128	300	300
Fe^{2+} (mg/l)	0.06	0.07	0.13	0.14	0.15	0.15	0.3	0.4
F^- (mg/l)	0.91	0.87	0.84	0.81	0.77	0.76	1.5	1.5
Cl^- (mg/l)	0	0	0	0	0	0	250	250
FCR (mg/l)	0	0	0	0	0	0	0.2-0.5	0.2-0.5
PO_4^{2-} (mg/l)	1.46	0.67	0.36	1.20	0.61	0.58	-	-
NO_3^- (mg/l)	12.84	12.34	12.51	12.04	12.74	12.64	50	50
NH_3 (mg/l)	0.16	0.12	0.14	0.14	0.17	0.17	1.5	1.5

The one way analysis of variance (ANOVA) test showed the significant differences in mean values of all selected physico-chemical parameters among the various sampling sites at $p < 0.05$ significant level except temperature.

Bacteriological Quality Analysis

In all of the selected sampling points namely the source, the reservoir, the pipeline and the household container, no bacteriological contamination was observed. The mean values for total coliform and faecal coliform for all sampling points were within the limits of WHO and Ethiopian water quality standards (0CFU/100ml). The reason for bacterial un-contamination of water at all sampling sites was due to the quality of the source water even if poor sanitation condition was observed around some public taps during the survey. Besides, the high temperature of water beyond the WHO standard did not cause the growth of bacteria in the water.

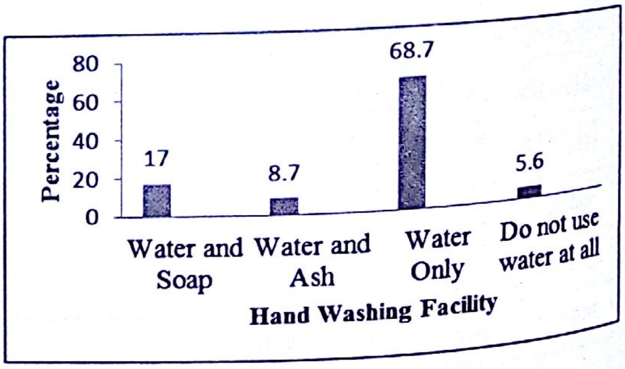
Sanitary and Hygienic Practices

Existence of Latrines

The results presented in this section are based on household survey and personal observation. The results revealed that 100% (195) of the respondents that are included in this survey reported the existence of latrine in the household compound. This implies that the latrine coverage in the town is 100%. But, this does not mean that the sanitation coverage is 100%. Although the latrine coverage is 100%, sanitation problems like poor awareness on sanitary and hygienic practices, lack of using hand washing facility after defecation and poor disposal method of wastes are still there. The result of key informant interview and focus group discussion shows the occurrence of sanitation related diseases like diarrhea and typhoid although the town's latrine coverage reached 100%. In the study area, three types of latrines were commonly constructed: pit latrine with walls but without roof, pit latrine with closed wall and roof, and open pit latrine without house. On the average, 88.2% (179) of the households had latrines with a wall and roof; 6.7% (13) of the respondents had pit latrines with closed walls but without roof; 1.5% of the households had open pit latrines. The remaining 3.6% (3) of the households had latrines with bowls.

Materials Used For Washing Hands after Defecation

Figure 3: Hand Washing Facility after Defecation



Disposing Liquid and Solid Wastes

Good hygiene practices (especially hand-washing with soap after defecating and before preparing food, and safe disposal of children's faeces) prevent diarrhea (UNICEF, 2008). Disposal of solid and liquid wastes in open field is a usual activity in the study area. During his stay in the study area, the researcher observed the people that were disposing wastes of different type in open field outside their houses. Of the total respondents, 53.8% (105) used private sanitary pit to dispose waste generated from their house. The remaining 46.2% (90) of the respondents did not have private sanitary pit; as a result, they disposed the waste generated from their house including the baby feces anywhere else.

Conclusion and Recommendation

Conclusion

This study has assessed the nature of potable water supply and sanitation in Bedesa town. Regardless of the substantial attention paid to water supply in the study area over the years, inadequate water supply remains one of the major problems. The findings of this study revealed that the average per capita domestic water consumption of the town was found to be 9.6 l/c/d for the base year (2014) which only satisfies 48% of the minimum urban water consumption value set by WHO as a basic need (20 l/c/day). Findings also revealed that nearly all of the people that have pipe water in their houses are not satisfied with the water supply; therefore, the use of alternative sources of water is indispensable.

The result of water quality test revealed that average values for all selected physico-chemical and bacteriological water quality parameters were found within the acceptable limits of WHO and Ethiopian water quality standards. But, the mean value of temperature was beyond the recommended WHO value (<15 °C). Similarly, sanitation situation in the town was not good and encouraging. In general, the findings of this study revealed that Bedesa town was not provided with access to adequate water supply and basic sanitation.

Recommendation

Based on the findings, the following recommendations are made:

* The development of new sources and expansion of the existing sources should take place in order to meet increasing demand for water.
* Water demand projection should consider population growth and improvement in living standards of the people.
* There should be provision of alternative sources of water supply in strategic locations in the town.
* To maintain the quality of existing water source, participation of all stakeholders should be undertaken followed by regular monitoring and disinfection with chlorine.
* To promote sanitation, regular inspection of private and public latrines, awareness creation on personal hygiene and environmental sanitation should be carried out by all concerned bodies and offices of the town.
* Further study should be carried out in order to discover and know the problems of water supply system and sanitation situation of the town.

REFERENCES

Andrea C. Telmo, 2002. A Water Supply and Sanitation Study of the Village Of Gouansolo in Mali, West Africa

Ethiopian Standards (ES). 2002."DrinkingWater Specifications" Quality and Standards

Authority of Ethiopia.

Federal Republic of Nigeria (FRN).2000. Water Supply and Sanitation Interim Strategy Note. Retrieved

March 29, http://siteresources.worldbank.org/NIGERIAEXTN/Resources/wss_1100pdf

JMP. 2006. Meeting the MDG water and sanitation target: the Urban and rural challenge of the decade. http://www.who.int/water_sanitation_health/monitoring/jmpfinal.pdf

[Accessed 20 March 2011]

Ministry of Water Resources (MoWR). 2006. Universal access program (UAP) for water supply and sanitation services from 2006 to 2012. Addis Ababa, Ethiopia.

UNICEF. 2008. United Nations Children's Fund (UNICEF) hand book on water quality, New York,

UNICEF. 2006. Meeting the MDG Drinking Water and Sanitation Target, the Urban and Rural Challenge of the Decade, Geneva, Switzerland. Decade, Geneva, Switzerland.

WHO. 2008. 'Access to improved drinking-water sources and to improved sanitation (percentage) 'http://www.who.int/whosis/indicators/compendium/2008/2wst/en/ [Accessed10 may 2011]

WHO. 2008. Guidelines for Drinking Water Quality, Third Edition.Vol 1: Recommendations. World Health Organization, Geneva.

WHO and UNICEF. 2006. Meeting the MDG Drinking Water and Sanitation: The Urban Challenge of the Decade

WHO. 2003a. Water, sanitation and health. Geneva, World Health Organization.

WHO. 2002. Guidelines for Drinking Water Quality, Vol.3. Water Quality in Developing Countries, World Health Organization, Switzerland, Geneva

WUP. 2003. Better Water and Sanitation for the urban poor. Good practice document from sub Saharan Africa. Water Utility Partnership for Capacity Building in Africa.

Erosion Hazard Assessment, Case study of Dhidhessa Sub Basin

Girma Nigusse

OWWDSE W/Wolega, girming@yahoo.com Tel. +251 911 83 35 68

Abstract

Soil erosion is a natural organic process, which persistently changes the surface in all climatic zones of the earth. It's considered as one of the most serious man-made impacts of deforestation on the environment. Erosion hazard assessment of Dhidhessa sub basin is carried out to prepare potential and actual erosion hazard maps for the sub basin using GIS technologies. The methodology for the soil erosion hazard study has encompassed survey and investigation of the study area, collection of relevant secondary data, review of literature and interpretation of image. Erosion hazard prediction of the area was made using Universal Soil Loss Equation model (USLE) developed by Wischmeier and Smith (1978), and identified that soil loss in the study area due to sheet and rill erosion varies from less than 5 ton/ha/year to 533.52 ton/ha/year. Accordingly, 23.5% of the soil loss is within the magnitude of less than or equal to 5% (very low), whereas around 16% of the soil loss is within a very high range (>60) tons per ha per annum. Soil erosion has many direct and indirect impacts on surface and sub-surface water resource and productivity of the area. So that actions should be taken to minimize erosion risks in the area.

Key Words: USLE, Dhidhessa sub basin, actual soil loss, potential soil loss, Erosion hazard map

Introduction

Soil erosion is a natural organic process, which persistently changes the surface in all climatic zones of the earth. Generally it's considered to be one of the most serious man-made impacts of deforestation on the environment. Soil erosion in agricultural system is a very important problem to manage. Soil can be eroded away by wind and water. Water erosion occurs only on slope lands and its severity increases with increased slope.

Soil erosion by water is a serious problem in the sub basin. Soil erosion process is influenced by biophysical environment comprising soil, climate, topography and ground cover and interactions between them. Soil erodibility; susceptibility of soil to agent of erosion is determined by inherent soil properties e.g., texture, structure, soil organic matter content, clay minerals, exchangeable cations and water retention and transmission properties (Nill, D *et.al.*, 1996). Climatic erosivity includes drop size distribution and intensity of rain, amount and frequency of rainfall, run -off amount and velocity, and wind velocity. Terrain characteristics that influence soil erosion are; slope gradient, length, aspect and shape. Ground cover exerts a strong moderating impact on dissipating the energy supplied by agents of soil erosion. Furthermore, the effect of biophysical processes governing soil erosion is influenced by economic, social and political causes (Nill, D., *et.al.,* 1996).

Objectives

The objectives of the study were:

To prepare potential soil erosion hazard map

To prepare actual soil erosion hazard map using GIS technologies

Materials and Methods

Description of the study area

The project area is located in West Oromia National Regional State. Most part of the project area lies in UTM zone 37 and the rest lies in UTM zone 36 with a Geographical extent of 850000m – 1145000m North and 125000m – 305000m East, within an elevation range of 820 to 3200m a.s.l. The total area of the projects site is **2,684,055** ha.

Mean annual precipitation range of the sub basin varies from 1160 mm to 2113 mm. The average minimum and maximum temperature varies from 11.3 to 23.17c°. The area is characterized by rugged topography and dissected gorges.

Methodology of the Study

Review of previous studies and interpretation of available spot and land sat image were made, and base map was prepared. Secondary data like LU/LC, Soil Physico-Chemical properties, Metrological data and farming system data were collected.

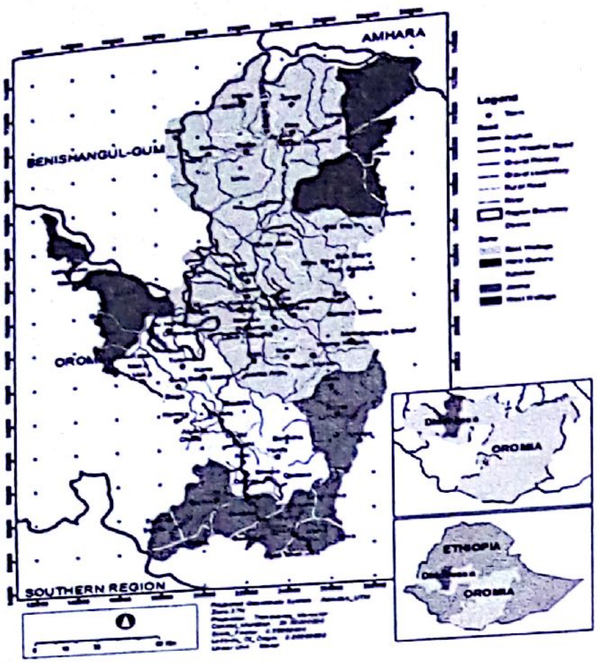


Figure 1 Location Map of Dhidhessa Sub basin

Primary data were obtained through field observation and investigation on the extent and degree of soil erosion through extensive travelling to different parts of the sub basin.

Selection of models

The most satisfactory methods of erosion hazard assessment are based on predicted soil losses by modeling the determinants of climate, soil, topography, vegetation or cover factors and management practices (Nill, D., *et.al.*, 1996). There are a wide range of erosion hazard assessment models currently in use around the world. These models are grouped into two broad categories: physical (process) based and empirical (Morgan, 2005).

Physical models are based on mathematical equations to describe the processes involved in the model, taking account of the law of conservation of mass and energy. They predict the spatial distribution of runoff and sediment over the land surface during individual storm in addition to total runoff and soil loss and mainly applicable to small farm fields to small catchments.

Empirical models are based on identifying statistically significant relationships between assumed important variables where a reasonable database exists. The most commonly and widely used empirical model is the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). USLE estimates long-time average annual soil loss from rills and inter-rills.

Both groups of models have merits and demerits, and are developed for application in certain locations under certain conditions. Under the Ethiopian conditions, most of the models can't simply be applied because of data gaps and applicability issues. However, USLE application to the Ethiopian environment has a better ground and substantiated through empirical research conducted during 1980s by the Soil Conservation Research Project of the Community Forests and Soil Conservation Development Department (Hurni, 1985).

Methodology and Techniques

The universal soil loss equation is an empirical model developed by Wischmeier and Smith (1978), was employed to assess the amount of soil loss existed in the area. Mathematically the equation is denoted by: A (ton/ha/year) = R * K * L * S * C * P.

Result and Discussion

An empirical model developed by Wischmeir and Smith (1978), was employed to assess the amount of soil loss existed in the area. A = R * K * L * S * C * P. in ton/ha/year

Rainfall Erosivity Factor (R-Factor)

The Rainfall erosivity factor (R) was analyzed based on Hurni (1985), employing the equation $R = -8.12 + 0.562 * P$.

The mean annual rainfall data of 20 years (1985 to 2005) derived from 28 rainfall stations were considered to estimate R-factor. The calculated R factor for each station was converted to raster surface with 30m grid cell using IDW interpolation techniques on Arc GIS.

Soil Erodibility Factor (K-Factor)

Soil texture was employed to determine the K factor. Based on the recent soil survey study in the area; six textural classes were identified. After assigning values for each soil textural classes based on their organic matter content, the soil map was reclassified using adopted K values by Taffa Tulu, (2011) with a grid map of 30m-cell size using IDW interpolation techniques. K value ranges from 0 to 1. Taffa Tulu. (2011) and it was multiplied by **0.1317** to change it in to SI unit.

Slope-Length and Slope Steepness Factor (LS-Factor)each

the soil map was reclassified using adopted K values by Taffa Tulu, (2011) with a grid map of 30m-cell size using IDW interpolation techniques. K value ranges from 0 to 1. Taffa Tulu. (2011) and it was multiplied by **0.1317** to change it in to SI unit.

Slope-Length and Slope Steepness Factor (LS -Factor)

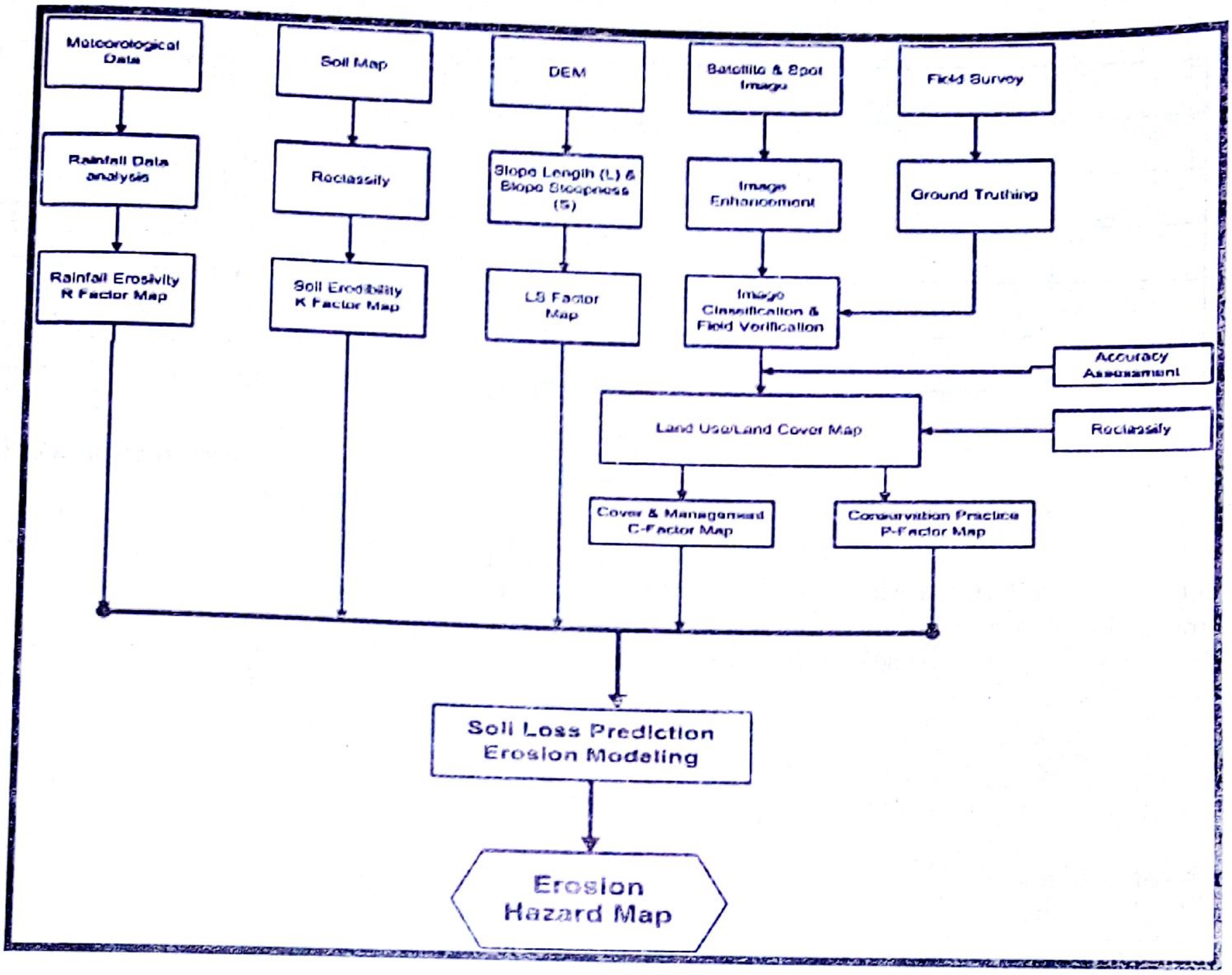


Figure 2 Methodological flow chart followed in the erosion prediction activities.

From other major factors contributing to soil erosion, topography is relatively stable which can remain fairly constant over time. In the present soil erosion study slope-length and slope steepness are used to reflect the effect of topography on erosion. Slope gradient factor (S-factor) was computed using the formula recommended by Griffin et.al (1988). **S = (pow [(sin(slope)*0.01745) / 0.09,1.3])**

For erosion hazard assessment at a scale of 1: 250,000 or larger slope length factor (L- Factor) could be adapted constant figure of 2.5 (Hurni, 1985), cited in Land Evaluation manual. And according to the same author (Hurni, 1985) which was modified to suit Ethiopia local conditions the maximum L-factor was 3.8 for a slope length of 320m. Therefore for present study with the scale of 1: 50,000, a constant value of 2.5 was adopted. Then LS-Factor was computed from the equation:- **LS = 2.5*(pow [(sin(slope)*0.01745) / 0.09,1.3]), slope in degree**

Cover and Management factor (C-Factor)

In erosion hazard assessment of present study 20 LU/LC types were identified, land-cover indexes for different LU/LC types suggested by Hurni (1985) was used. Accordingly, higher C-factor values indicate higher risk of soil erosion. C value for the current study area ranges from 0.001 to 0.65.

Erosion Control Practice Factor (P-Factor)

Estimation of the P-factor, for the study area, was carried out taking in to account the local management practices which were observed during the field survey. In this study, P is calculated for agricultural lands; for all other lands it is assumed as one because there is no any control practice measures. Thus, value of P factor was` assigned to cultivated lands based on the adopted P-value by Hurni (1985).

Assessment of potential and Actual Soil Loss

Potential soil loss

The rainfall erosivity (R-factor), soil erodibility (K-factor), topographic factor (LS-factor) as an elements of USLE equation are considered as naturally occurring factors determining sheet and rill-erosion process. Together, they are considered as the erosion susceptibility or potential erosion or soil loss for the area.

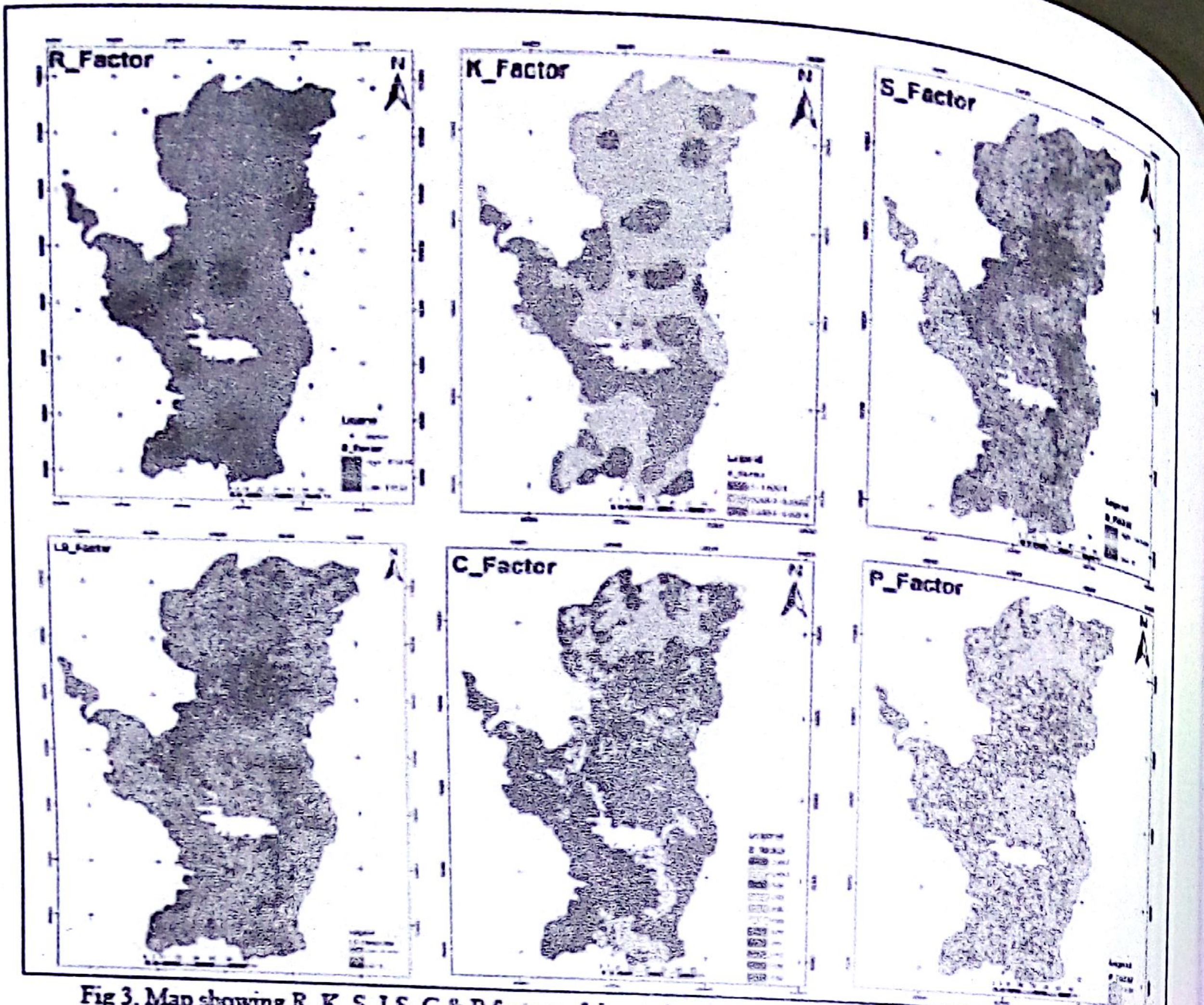


Fig 3. Map showing R, K, S, LS, C & P factors of the study area

The three factors are multiplied to get the potential soil loss from the sub basin by ArcGIS software spatial analysis raster calculator function using the following syntax:

Raster calculator> potential erosion = R- factor * K-factor * LS- factor

The quantitative output of estimated potential soil loss from Dhidhessa sub basin varied from **0 to 1010.82 ton/ha/year.** The spatial pattern of potential erosion indicated that 92.12% of the catchment is potentially endangered by erosions of various intensity. The highest potential endangerment is strongly associated to mountains and hills. The estimated soil loss is reclassified and presented in to five ordinal classes as shown in Table 1.

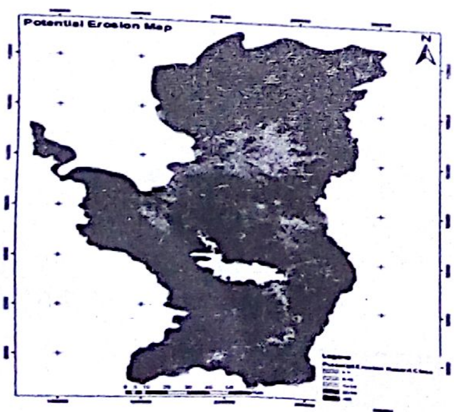


Figure 4 Potential soil erosion map

Table 1 Potential Erosion Class and its proportional coverage in the sub basin.

S/N	Soil loss(ton/ha/year)	Soil Erosion Risk Class	Area (Ha)	%
1	0-5	Very Low	91216.46	3.40
2	5-12	Low	47765.90	1.78
3	12-25	Medium	72608.12	2.71
4	25-60	High	441978.23	16.47
5	>60	Very High	2030486.28	75.65
Total			**2684055.00**	**100.00**

Table 1 - Soil erosion risk Classes and equivalent RUSLE values (Bergsma, 1986)

Actual soil loss

The actual erosion assessment is based on the principles of USLE model, which multiplies the six parameters; rainfall erosivity, soil erodibility, slope gradient and length, land cover, and soil conservation practices. The application of model was by using raster calculator method of ArcGIS spatial analysis function, which enables the multiplication of the parameters cell by cell.

Accordingly, the quantitative output of estimated actual soil loss from Dhidhessa sub basin varied from **0 to 533.52 ton/ha/year.** The first two classes are considered in the range of soil loss tolerance values. Medium and high classes need conservation applications to maintain a sustainable productivity, while the last class (very high), is very dangerous because it can be destructive in few years if no intervention are done and soil loss level is maintained constant in the future. In the sub basin about 39.4% of land is grouped under cultivated land use/cover type. The result shows that, 15.97% of the study area is under erosion prone.

Raster Calculator> Actual soil loss, A = R- factor*K-factor*LS-factor* C-factor *P-factor

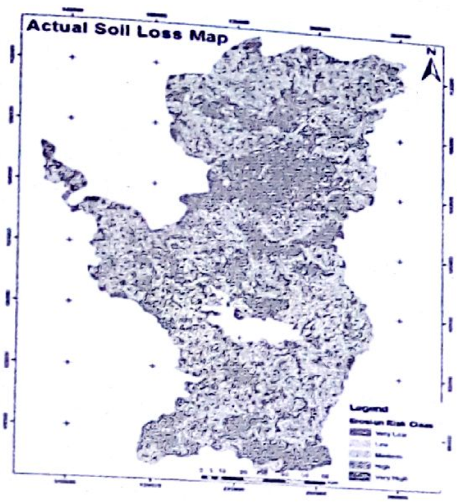


Figure 5 Actual soil erosion map

Table 2 Actual Soil erosion risk class in the sub basin.

S/N	Soil loss(ton/ha/year)	Soil Erosion Risk Class	Area (ha)	%
1	0-5	Very Low	630368.15	23.49
2	5-12	Low	336792.48	12.55
3	12-25	Medium	452273.82	16.85
4	25-60	High	836031.43	31.15
5	>60	Very High	428589.12	15.97
Total			**2684055.00**	**100.00**

Table 1- Soil erosion risk Classes and equivalent RUSLE values (Bergsma, 1986)

Conclusion and Recommendation

Conclusion

Current Erosion hazard assessment is conducted at a scale of 1:50,000.

- The methodology has employed collection of relevant

secondary data, interpretation of satellite imageries and topographic maps,

- Universal Soil Loss Equation model (USLE) is adopted to predict sheet & rill erosion.
- Using USLE model a potential soil loss of **0 to 1010.82ton/ha/year** was estimated.
- The highest potential erosion is strongly allied to mountains areas of the sub basin.
- After consideration of land use land cover and conservation practice factor soil loss from the area (actual soil loss) is estimated to range from **0 to 533.52ton/ha/year.**
- Accordingly about 47.12% of the sub basin was subjected to high to very high soil loss.

Recommendation

- Intensively cultivated lands, which contribute a lion's share to soil loss, should be treated as erosion hazard zone and water shade management practices should be adopted.
- Appropriate SWC measures should be adopted in the area.
- Attention should be given on the expansion of farm lands on to marginal areas & forests.
- Detail assessment of erosion hazard in large scale should be recommended.

Acknowledgment

I would like to thanks Oromia Water Works Design and Supervision Enterprise (OWWDSE) for their financial and logistic support.

References

Hurni, H. 1985 Erosion-productivity conservation systems in Ethiopia. Paper presented at IV ISCO conference, venezuala.

Morgan, R. P. C., 2005. Soil erosion and conservation. Third edition. Blackwell publishing, National Soil Resources Institute, Cranfield University.Blackwell Science Limited. 304 p.

Nill, D.; Schwertmann, U; Sabel-Koschella, U,; Bernard, M.; Breuer, J. 1996. Soil Erosion by Water in Africa; Principles, Prediction and Protection. GTZ. 292p.

Taffa Tulu, 2011. Soil and Water Conservation for Sustainable Agriculture, Addis Ababa.

Wischmeier, W. H. & Smith, D. D. (1978) Predicting Rainfall Erosion Losses to Conservation Planning. US

Hydraulic Performance Evaluation of Hare Community Managed Irrigation Scheme, Southern Ethiopia

Mamuye Tebeba[1] and MekonenAyana (PhD)[2]

ANRS BoWRD[1] and Arba Minch University[2]

bic.ma12@gmail.com

Abstract

Performance based management is a principal approach to improve the scheme performances. However, in Ethiopia performance evaluation of irrigation schemes is rarely conducted. The potential benefits of Hare community managed irrigation scheme are hardly realized the required benefits. The objective of this study was to assess the hydraulic performance ofHare irrigation system. The study was carried out during the irrigation season from September to December, 2014. Hydraulic performance of the irrigation system was evaluated using nineprocess performance indicators. The results indicate that,the values of adequacy, dependability and equity are found to be 0.64, 0.21 and 0.34 respectively. The equity ratio of water distribution of head to tail is 3.52; which depictsthe head reach farmers received more water than the tail. Average water deficit of the system is 36 percent; the main canal supplies less water than the demand to the delivery points.As per the results of the study, water delivery performance of the scheme can be considered as poor. The values of water surface elevation ratio, effectiveness of infrastructure and delivery duration ratio are found to be 91,15.9 and 133.36 percent respectively. It displayed that high system maintenance is required. Generally, the performance of the irrigation system is poor. Therefore, capacity building of users, adequate operation and maintenances of the system, improving diversion capacity of the scheme and providing flow control and measurement structures are required to improve the irrigation system performance.

Keywords: Hydraulic performance,process indicators, Hare irrigation scheme irrigation service, water delivery and maintenance indicators.

INTRODUCTION

Water scarcity is a potential constraint to produce more foods to meet the demands of increasing world population. One possible approach to conserve this scarce resource might be through improving the performance of existing irrigation schemes (SmallandSvendsen,1992).

Ethiopia has enormous cultivable land, but only current irrigation schemes covering about 640,000ha (Seleshi,2010).

The government is undertaken development of several new irrigation projects, but the per of romance of existing irrigation schemesaregivenlessconsidera-tion.Inmanyoftheseschemes,watermanagementactivitiesare performedbythefarmersthemselves,yet they lack technical expertise to effectively manage their water (Zeleke, 2011). Theperformanceofmanyirrigationsystemsaresignificant-lybelowtheirpotentialduetoanumberofshortcomings;includi ngpoordesign,construction,operation,maintenance,welleffe ctivewatercontrolandmeasurementsmisallocation (Degirmenci*et al.*, 2003 and Aklilu,2006).

Hare irrigation scheme is allowed to the farmers applying irrigation and has enabled them frequently to harvest twice per year. However, due to lack of frequent training for water application and management, farmers spent water more hours per day. The water distribution approach in the scheme is fixed rotational water delivery scheduling, yet the water control and regulating mechanisms are traditional using barriers like leaves and stones. With increased population growth and the erratic nature of rain fall, the computation of water users in the area increased from time to time. This limits the quality and quantity of agricultural productivities. The delivery of fair share of water to the user is not clearly understood, it was discovered that this situation could be artificially created to benefit few (corruption). Besides, due to urbanization breaching through and high economic escalation agricultural activities began to decline and the irrigation water is shared with municipalities and other purposes. In this condition appraisal of the performance of water delivery system and maintenance requirement becomes vital to ensure good functioning of the irrigation system. Therefore, this study was conducted on hydraulic performance assessment of Hare community managed irrigation scheme using process performance indicators. It was addressed to analyze the performance of irrigation system in relation to water delivery performance indicators and maintenance requirements of the scheme.

MATERIALSANDMETHODS

Descriptions of the study area

Hare irrigation scheme is located in the Abaya-Chemo sub -basin of Gamo Gofa Zone, Southern regional state of Ethiopia. The topography of the command area is de-scribed as flat to gently sloping plain. The watershed is situated between 6°03' and 6°18' North and 37° 27' and 37° 37'East and has an area of 187 km². The average elevation isabout1169m am.sl; and its command area lies between 6°06'40" and 6°06'28" North and 37° 33'53" and 37°36'48" East. The scheme abstracts water from Hare River. Smallholder agriculture is the dominant land use in the watershed; irrigated cash crop is the predominant. The designed and actual command area in irrigation was 1336 and 1131.87 ha respectively.

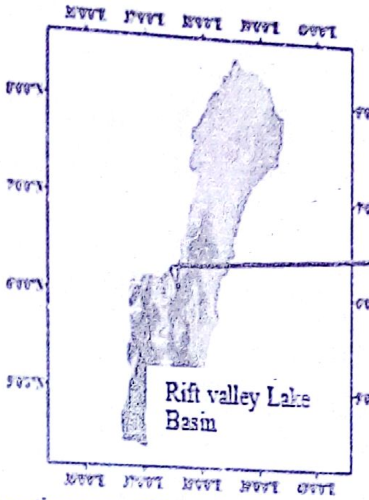
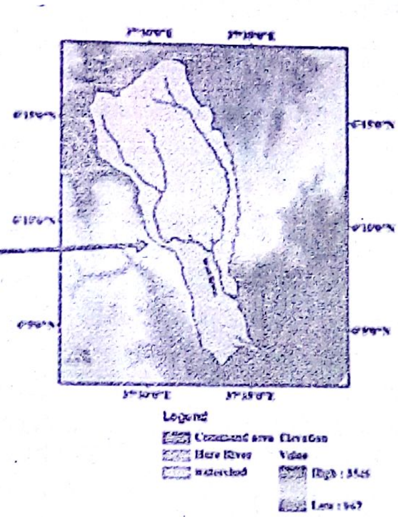


Figure 3.1 Location map of Hare irrigation scheme



Hare watershed and command area

Back ground of the scheme

The modern diversion irrigation scheme was intended to serve around 1798houscholds of Chano Chelba and Chano Mille Kebeles. The design capacity of the intake structure is 2 m^3/s with a maximum discharge capacity of 2.4 m^3/s. The networking system of canals in the irrigation area consists of one main canal with eight branch canals. A small portion of the main canal is rectangular masonry and the major portion is trapezoidal lined and unlined canal. The length of the main canal was about 5.31 km long and totally had 23.85km length of branch canals. The main canal length which actually gives service to the benefi-ciary is 3.89 km. The design layout of the scheme consists 162 various structures which includes turnouts, lateral gates, aqueduct, control and recession gates, bridges, flumes and drop structures (HIPDDR, 1989).

Methods

Data sources and methods of data collection

In this study the data were collected from primary and secondary sources. The primary data were collected in direct measurement from fields. Such activity includes: measurements of discharging through the branch off take canals, measurement of actual water surface elevation in the main canal, filed observations, hydraulic design of Par shall flume and volume of water required in the irrigation system. The secondary data were collected from agricul-tural and rural development offices and Arba Minch me-trology station. Climate data, irrigated crops, actual com-mand are asand designed features of the scheme are major data which were utilized in the study.

Discharge Measurements

In this study two methods were used for measuring anal irrigation water supply. These are calibrated Par shall flume and Current meter. The flow measurements were taken on the seven branch off take canals. A GEOPACKS Current flow meter was used to measure the flow veloci-ties in the canals. Two and six inch Par shall flumes were installed at the flow measurement location and frequent readings were taken. The discharge of canals resulting from the depth-flow relationship in par shall flumes were calculated in free flow conditions. The measurements were taken at the branch off take canals just after abstrac-tion points along the distribution or branching canals. Based on the settled water delivery plan, the measurement of actual discharges in each branch off take canals were taken on 15 days per three months (five days/month) and then converted into an average monthly rate.

Water surface elevation measurements (WSE)

Water surface elevation of the main canal was measured in the reaches of the canal. In middle and tail reach, actual WSE data were taken from eight monitoring stations classified with the canal length in 0.162 km interval, yet the data were taken in nine monitoring stations in the head reach. Generally, actual WSE data were taken on 25 inspection stations along the main canal.

Data analysis

Hydraulic performance of the irrigation system was evaluated using nine performance indicators. Performance evaluation using process indicators consists specifically measuring the extent to which the goals and required benefits are being achieved. It was investigated based on the data that were collected during September to December, 2014 in one irrigation season. While, water delivery performances were analyzed using the observed data in October to December, 2014. The choice of these months was arranged due to the fact that, it is hardly rain and almost all fields are irrigated. A water delivery performance was designated to evaluate on the main canal at head, middle and tail reaches. The main canal system performance with respect to water delivery indicators was estimated based on the monthly required and delivered discharge.

Water delivery performance indicators

The water delivery performance parameters like adequacy, equity and dependability have been proposed by Clemmens and Bos (1990); and Moldenand Gates (1990). According to Molden and Gates (1990), the performance of the system was classified as good, fair or poor.

Dependability (PD): It is defined as the temporal uniformity of the ratio of delivered amount of water to the required or scheduled amount over a region. Such parameter is defined as:

$$PD = \frac{1}{R} \ldots\ldots\ldots (3.1)$$

Where, $Cv_T$is temporal coefficient of variation of the ratio Q_D/Q_Rover a region S and a time T.

Adequacy (PA): Adequacy displays the extent to which the total water deliveries are sufficient to fulfill the needs of the crops in a specific growing season. It relates to the actual delivery to required amounts of water needed for the crop irrigation (Molden and Gates, 1990).

$$PA = \frac{1}{T}\sum_{T} \ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Where, PA $=Q_D/Q_R$, if $Q_D \leq Q_R$, otherwise PA=1, S is the site where canals are located. $Q_D$is actual amount of water delivered by the system and Q_R is required discharge.

Equity (PE): Equity as related to water delivery system can be defined as the delivery of the fair shares of water to the users throughout the system. An appropriate measure of the performance

of the system with equity would be the average relative spatial variability of the ratio of amount delivered to the amount required over the time period of interest. The measure is given by:

$$PE = \frac{1}{T}\sum_{T} CvR(\frac{Qd}{Qr}) \ldots\ldots\ldots\ldots\ldots (3.3)$$

where CV_R is the special coefficient of variation of the ratio of delivered water to required water over the region R and it is the time period.

Equity Ratio for Head

and Tail (ERHT): This indicator focused on the equity of water distribution for head and tail at different levels of a system. It can assist to identify head and tail difference at the level of the system; and to address problems as a result. The ratio is defined as:

$$ERHT(MDR) = \frac{\frac{1}{n}\sum_{t=1}^{t=n} MDR\ (head)}{\frac{1}{n}\sum_{t=1}^{t=n} MDR(tail)} \ldots\ldots\ldots\ldots\ldots (3.4)$$

The value of MDR is described as the ratio of Q_D with Q_R, n is the number of periods monitored

Deficiency: The value of deficiency is a quantitative measure of the dissatisfaction'sof users. The parameter will help the system managers and users to take corrective measurements for system improvements in deficit areas. A measure of deficiency is given as the ratio of temporal and spatial average of water deficiencyto the required amount (Q_R) (Binoy*et al.*, 2013).

$$PDF = \frac{1}{T}\sum_{T}(\frac{1}{S}\sum_{S}\frac{QR - QD}{QR} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

$$PDF = \frac{QR-QD}{QR}$$, if $Q_R > Q_D$, Otherwise =0

Table 3.1 Range of water delivery performance indicators (Molden and Gates, 1990)

Table 3.1 Range of water delivery performance indicators (Molden and Gates, 1990)

Performance indicators	Range			
	Poor	Fair	Good	Excellent
PD	>0.20	0.11-0.2	0.00-0.10	
PA	<0.80	0.80-0.89	0.90-1.00	
PE	>0.25	0.11-0.25	0.00-0.10	
ERHT(MDR)	<0.7 or > 1.3	0.7-0.79 and 1.21-1.3	0.8-0.9& 1.1-1.2	0.90-1.10

Maintenance indicators

Maintenance performance inspection of the irrigation scheme would provide to insight the feature of maintenancesituations.Hydraulic performance of the scheme was also evaluated with maintenance performance indicators. It was estimated through the indicators recommended by Shafique (1993), Bos (1997); Kloezen and Garces (1998) and Bos*et al.* (2005). Maintenance requirements of the system were observed according to the maintenance indicators of water surface elevation ratio, effectiveness of infrastructure, delivery duration ratio and sustainability of irrigable area. The physical structures in its operational condition were categorized as operative, nearly operative, nearly inoperative and inoperative. If at least one of the following conditions are in effect: broken anddamaging of the structure, change of canal cross-section, scouring of canal section, missing of flow control and measuringstructures, sedimentation and weedgrowth (Samad and Vermillion, 1998).

Effectiveness of infrastructure: The study was focused on the irrigation system components with the spillway and weir except the drainage and field application systems. The existing condition of the main and branch canals were inspected in itsoperating length alone. The ratio is:

$$\text{Effectiveness of infrastructure} = \frac{\text{Number of functioning structures}}{\text{Total number of structures initially installed}} \quad \text{......(3.6)}$$

Water surface elevation ratio (WSER): This indicator provides to predict the impact of sedimentation and erosion problems on the physical irrigation system(Shafique, 1993).

$$WSER = \frac{\text{Actuall water surface elevation at FSL}}{\text{Intended water surface elevation at FSL}} \quad \text{......(3.7)}$$

DeliveryDurationRatio (DDR): are both maintenance and water utility performance indicator's, it is described as the ratio of actual and intended duration of supply in day.

$$DDR = \frac{Dac}{DI} \quad \text{......(3.8)}$$

Sustainability of irrigated area (SI): Is measured as the ratio of existing area under irrigation to the planned irrigated area (Vermillion, 2000):

$$SI = \frac{\text{Actuall irrigated area}}{\text{Designed irrigated area}} \quad \text{......(3.9)}$$

Determination of the amount of water required in the irrigation system

The amount of water needed for the irrigated crop fields was determined using CROPWAT version 8program. Crop water requirements, irrigation requirements (IR) and scheme water

supply for varying crop patterns was estimated based on the soil, climate, and crop patterns. Daily and monthly reference Crops Evapo-transpiration (ETO) were estimated by the Penman-Montecito method. The soil composition based on the textural triangle classification is clay loamwith41.91% sand, 27.97% silt and 30.12% clay (Belete, 2006). The hydraulic properties of the soil were determined based on the soil textural inputs from the percent sand, silt and clay using SPAW model (Saxton*et al.*, 1986).The CWR were then computed from the crop factor (Kc) and the ETO values for the crop planted. The value of effective rainfall was determined using USDA soil conservation service method (Clarke, 1998).The volume of water required (QR) to feed the main and branch canals were estimated with the product of IR and the command area (ha) served for irrigation practice by assuming an irrigation efficiency (IE) of 31 per cent (Belete , 2006).

RESULT AND DISCUSIONS

Evaluation of water delivery performance indicators

Adequacy

The adequacy value is calculated using equation (3.2). The spatial and temporal mean values of adequacy in the system are given in Table 4.1.

Table 4. 1 Average adequacy and deficiency of water distribution in the system

	Head		Middle		Tail			Spatial Ava	
Month	BR_1	BR_2	BR_3	BR_4	BR_5	BR_6	BR_7	PA	PDF
October	1.00	0.80	0.63	0.60	0.64	0.53	0.63	0.69	0.31
November	1.00	0.87	0.68	0.80	0.76	0.43	0.39	0.71	0.29
December	1.00	0.73	0.37	0.43	0.43	0.34	0.36	0.52	0.48
Temporal	1.00	0.80	0.56	0.61	0.61	0.43	0.46		
Ava PA	0.90		0.59		0.50			0.64	
Temporal	0.00	0.20	0.44	0.39	0.39	0.57	0.54		
AvaPDF	0.10		0.41		0.46				0.36

Average spatial and temporal values of adequacy are 0.69, 0.71 and 0.52 in October, November and December, and 0.9, 0.59 and 0.5 at head; middle and tail reach of the system respectively. The overall adequacy value of the system is found to be 0.64. The spatial and temporal average adequacy of the scheme is poor except in the head reach of the distribution system. The temporal adequacy in the head reachfalls in the good range. However, theoverall average adequacy during the season for the entire command of the main canal is found to be poor.

Dependability

The measurementof dependability was computed using equation(3.1). The results of dependability are presented in Table 4.2.

Table 4. 2 Dependability of water supplied and Equity of water distribution on the system

	Head		Middle		Tail					
Month	BR_1	BR_2	BR_3	BR_4	BR_5	BR_6	BR_7	Average	Std.	CV,(PE)
October	1.00	0.80	0.63	0.60	0.64	0.53	0.63	0.69	0.16	0.23
November	1.00	0.87	0.68	0.80	0.76	0.43	0.39	0.71	0.22	0.32
December	1.00	0.73	0.37	0.43	0.43	0.34	0.36	0.52	0.25	0.48
Average	1.00	0.80	0.56	0.61	0.61	0.43	0.46			0.34
Std.	0.00	0.07	0.17	0.19	0.17	0.09	0.15			
CV,(PD)	0.00	0.09	0.30	0.30	0.28	0.21	0.32			
	0.05		0.30			0.27		0.21		

The average dependability (temporal coefficient of variation) values of head, middle and tail reach of a system are ranging from 0.05 to 0.27 with an overall average dependability of 0.21. The average dependability of the first branch canal is zero. As it can be seen from the result BR_1represents a reliable delivery of water (Table 4.2).Accordingly, the dependability of water distribution in the scheme at middle and tail reaches are poor (>0.2), while good in head reach of the distribution system.The performance of the entiresystem in termsof dependability of water distribution is foundin the unsatisfactory range; ithas been performed poor over the season.

Equity

Equity of water distribution was calculated as the coefficient of variation of the adequacy values between different locations using equation (3.3). The results of spatial coefficient of variation (PE) of water distribution over the investigation period are given in Table 4.2.Equity of water distribution in November and December is perceivedabove the standard of the faire rage; which is said to be poor. But, the distribution of water in October isfair. The head reach users received more water than the middle and the tail reach, however tail reach users aremost disadvantaged in the delivery of water (Table 4.2). Average overall equity of the delivery system is found to be 0.34 (Table 4.2). The result shows that equity of water distribution is poor over the entire system.Belete (2006) and Mekonen (2006) also found similar results in the study and suggested that almost upper end outlets were received more water than the tail end.

Equity Ratio for Head andTail (ERHT)

The ERHT was calculated using equation (3.4). Table 4.3displayedthe equity ratio for head and tail and the values of MDR.

Table 4.3 Equity ratio for Head and Tail (ERHT (MDR)) reach of the system

	Head			Tail		
	BR_1	BR_2	BR_5	BR_6	B_7	
Month	MDR	MDR	MDR	MDR	MDR	ERHT(MDR)
October	3.13	0.80	0.64	0.53	0.63	2.18
November	7.00	0.87	0.76	0.43	0.39	4.96
December	3.13	0.73	0.43	0.34	0.36	3.41
Average						3.52

The value of ERHT ranges from 2.18 to 4.96. The overall averagevalue of ERHT is found to be 3.52. The results of ERHT obtained here are poor. All the values of the ratio (ERHT) in the table are greater than one, indicating that the MDR of the head reach of the system is higher than the tail reach.The performance of the main canal is not found in a reasonable level with respect to ERHT (MDR). The head delivery systems receive more water than the tail in all months.

Deficiency of Water

The deficit of water delivery was calculatedby using equation (3.5).The results of spatial and temporal average value of deficit are presented in Table 4.1.The average temporal deficits in head reach are relatively lower. Yet shortage of water is not emerged in the first branch canal (Table 4.1). The deficits of the tail reach delivery system had been highest. Average spatial deficit in the conveyance system has beenobserved in all months. The spatial deficit is advanced in December mainly in branch canal six (BR_6). High spatial average deficit is happened in December. Average overall deficiency of the entire system is found to be 0.36 (36 percent). The delivery system supplied less waterthan the required in generally.

Maintenance performance of the system

Effectiveness of infrastructure

Effectiveness of infrastructure was estimated using equation (3.6). According to the design document, the total number of structures that wereinstalled in the irrigationscheme was 113, howeveronly 18 structures are currently functional. Hence,the value of effectiveness of infrastructure is estimated to be 15.9 percent. The value suggested that the maintenance activity of a system was very poor.

With regarding to canal operating condition, the physicalstates of canal length inspection areshowninTable4.4. The main canal section is found to be operative, nearly operative, nearly inoperative and inoperative with the corresponding value of4.86,67.50,0.90 and26.74 percent respectively. Whereas,0.08,79.63,9.07and11.23percentof the branch canals are operative, nearlyoperative, nearly inoperative and inoperative respectively.In the view of the survey displayed inTable 4.4, nearly larger percentage of the main and branch canal length were found to be inoperative in the tail reach.

Table 4. 4 Physical condition of canal length inspection

Location	Total length of canal(km)	Operative length (%)	Nearly operative (%)	Nearly inoperative (%)	Inoperative length (%)
Main canal	5.31	4.86	67.50	0.90	26.74
Branch canals	23.86	0.08	79.63	9.07	11.23

Water surface elevation ratio (WSER)

The parameter of WSER was computed using equation (3.7).The resultsare given in Table 4.5.

Table 4.5 Average Water Surface Elevation (WSE) statuses of the main canal

Location	Head		Middle		Tail		Over all	
	Dev. WSE	WSER	Dev. WSE	WSER	Dev. WSE	WSER	WSER	Dev. WSE
Average	0.05	0.94	0.13	0.84	0.05	0.94	0.91	0.07

Note: the result is based on mean level measurement of water depth at FSL in various main canal sections and all measurements are in meter unit.Dev.WSE is deviation of water surface elevation.

Note: the result is based on mean level measurement of water depth at FSL in various main canal sections and all measurements are in meter unit.Dev.WSE is deviation of water surface elevation.

As per the design document the intended water depth of the main canal from the canal bottom was 0.8 m at FSL with the discharge capacity of 2 m^3/s.whereas, the current average water surface elevation at FSL is found to be 0.73 m. Even though, overall average WSER was found to be 0.91. This shows a seven percent of WSE at FSL was reduced in the intended water depth of the main canal. The parameter of average WSER at head, middle and tail reaches of the main canal during the monitoring period is generally less than one, thus the main canal is infected by weed and sedimentation problem (Table 4.5).

Delivery Duration Ratio(DDR)

The value of DDRwas calculated using equation (3.8). As per the design document the intended duration of water delivery was 18 hours per day. However, because of the silting up of the canal system, malfunctioning of control structure, defective of ender main and secondary canals and due toshortage of water mainly for tail end beneficiaries, water delivery is neither timely nor reliable, sinceactual duration of water delivery is elongated to 24 hours per day.Therefore,DDR is 133.33 percent; showing the water distribution system is notdependable andthesystem maintenance is insufficient. The system needs further maintenance requirement.

Sustainability of irrigated area (SI)

As per the design document the intended command area that a scheme could potentially irrigated were 1336 ha, while the actual irrigated area in a cropping season are 1131.87 ha. Hence, SI is found to be 85 percent using equation (3.9). The irrigated areas of the irrigation scheme are reduced compared with the planned; however the reductions of command area were not due to the inability of the scheme water supplied to the farm with insufficient maintenance activity.

CONCLUSIONS AND RECOMMEDATIONS

Performance assessmentis a practical solution to provide different stakeholder with a better understanding of how the system can be effectively implemented to improve irrigation system performance. It helps to identify problems and management practice of irrigation system.In the main canal system, the performance of water delivery was found to be poor in terms ofadequacy, dependability, equity and equity ratio for head to tail. Likewise, the delivery system supplied less water than the required, which is considered as unsatisfactory with respect to deficit.This unsatisfactory performance of irrigation system could reduce the productivity of the farm and brings water related conflicts.

Maintenance performance indicators were considered the parameter of water surface elevation ratio, effectiveness of infrastructure, canal operating condition and delivery duration ratio. Generally, it was found that the maintenance performance of the system was very poor.Some parts of the structures are affected bysedimentation; weed growth, flooding anderosion problems. The main causes of low maintenance performance of the scheme have been due totechnical,social,managerial, institutional and financial issues.

In general, according to the result perceived, the performance of irrigation system is low. Therefore, a system to be performing well;thoughtful system management is required so as to achieve the required objectives of the scheme. Moreover, improvingwater management, adequate maintenance of irrigation infrastructures, capacity building of users in different aspects which can be support for improving irrigation water utilization, soil and water conservation practice is required to provide manifold benefits.

REFERENCE

klilu, A. (2006). *Assessment of irrigation system at Sille state farm*.Unpublished master thesis, Arba Minch University, Ethiopia.

Belete,B.(2006).*A cross system comparative assessments of Hare community managed irrigation schemes performance*. Unpublished master thesis, Arba Minch University, Ethiopia.

Bos, M. G. (1997). Performance indicators for irrigation and drainage, *Journal of Irrigation and Drainage Systems 11*(2), Kluwer, Dordrecht, p 119-137.

Bos,M.G.,Burton,M.A,and Molden,D. J.(2005).Irrigation and drainage performance assessment practical guidelines.*Journalof Centre forAdvanced Biomedical Imaging*, 22,Wallingford, UK, p 28-59.

Clarke, D. (1998). *CROPWAT version 4.2 for Windows, user guide*, University of Southampton, UK.

Clemmens, A.J. and Bos, M.G. (1990). Statistical methods for irrigation system water delivery performance evaluation, International Institute of Land Reclamation, 6700 A A. *Journals of Irrigation and Drainage System, 4*, Kluwer Academic, Wägeningen, The Netherlands, p 345-365.

Degirmenci, H., Buyukcangaz, H.and Kuscu, H. (2003). Assessment of irrigation scheme with comparative indicators in the South Easter Anatolia Project, Kahramanmaras sutcu Imam University, Turk. *Journal of Agriculter*, p 293.

Hare River Irrigation Project Construction Detail Drawing (HRIPdD), Ethiopia. (1989). Shanving S.H.A.A. NXI, The people Republic of China.

Kloezen,W.H.andGarces-Restrepo,C.(1998). Assessing-irrigation performance with comparative indicators: the case of Alto Rio Lerma irrigation district, Mexico, research report22.*JournalofIWMI*,Colombo,SriLanka, accessedon 12/11/2014, http://dlc.dlib.indiana.edu.

Aklilu, A. (2006). *Assessment of irrigation system at Sille state farm*.Unpublished master thesis, Arba Minch University, Ethiopia.

Belete,B.(2006).*Across system comparative assessments of Hare community managed irrigation schemes performance*. Unpublished master thesis, Arba Minch University, Ethiopia.

Bos, M. G. (1997). Performance indicators for irrigation and drainage, *Journal of Irrigation and Drainage Systems 11*(2), Kluwer, Dordrecht, p 119-137.

Bos,M.G.,Burton,M.A,and Molden,D. J.(2005).Irrigation and drainage performance assessment practical guidelines.*Journalof Centre forAdvanced Biomedical Imaging*, 22,Wallingford, UK, p 28-59.

Clarke, D. (1998). *CROPWAT version 4.2 for Windows, user guide*, University of Southampton, UK.

Clemmens, A.J. and Bos, M.G. (1990). Statistical methods for irrigation system water delivery performance evaluation, International Institute of Land Reclamation, 6700 A A. *Journals of Irrigation and Drainage System, 4*, Kluwer Academic, Wageningen, The Netherlands, p 345-365.

Degirmenci, H., Buyukcangaz, H.and Kuscu, H. (2003). Assessment of irrigation scheme with comparative indicators in the South Easter Anatolia Project, Kahramanmaras sutcu Imam University, Turk. *Journal of Agriculter*, p 293.

Hare River Irrigation Project Construction Detail Drawing (HRIPdD), Ethiopia. (1989). Shanving S.H.A.A. NXI, The people Republic of China.

Kloezen,W.H.andGarces-Restrepo,C.(1998). Assessing-irrigation performance with comparative indicators: the case of Alto Rio Lerma irrigation district, Mexico, research report22.*JournalofIWMI*,Colombo,SriLanka, accessedon 12/11/2014, http://dlc.dlib.indiana.edu.

Mekonen, A. (2006). *Assessment of irrigated agricultural system*. Hare irrigation scheme, Arba Minch, Ethiopia, p 11.

Molden, D.J. and Gates, K. (1990). Meassurments of evaluation of irrigation water delivery systems. *Journal of Irrigation and Drainage Engineering,116* (6), ASCE, p 804-823.

Seleshi, B. A. (2010).Irrigation potential in Ethiopia, constraints and opportunities for enhancing the system,*International Water Management Institute*, Ethiopia.

Shafique,M.S. (1993).*Performanceof the Gezira canals*.An internal reviewprogram, International Irrigation Management Institute, Sudan, Colombo, Sir Lanka.

Small,L.E. and Svendsen, M. (1992). A frame works for assessing irrigation performance. *Journal of Irrigation and Drainage System, 4* (4), Washington D.C, USA, p 283-312.

Vermillion, D. (2000). Guide to monitoring and evaluation of irrigation management transfer. *Journal of International Irrigation and Drainage*, USA.

Zeleke, A. (2011). Irrigation performance in community managed schemes: Assessment using comparative indicators and utility. *Journal of International Congress on Irrigation and Drainage*, Tehran, Iran.

The Effect of Soil Erosion on Reservoirs Life Expectancy

A case study on Belbela reservoir, Ethiopia

Mastewal Tesfaye[1], Prof. Dr. Charlotte De. Fraiture[2], Dr. Laszlo G. Hayde[2], Dr. Shreedhar Mskey[2]

[1] Water Works Design & Supervision Enterprise (WWDSE), Addis Ababa, Ethiopia, Email: mass2tes@yahoo.com.

[2] UNESCO-IHE Institute for Water Education, Delft, The Netherlands

Abstract

The outlet of Belbela watershed which is located in central highlands of Ethiopia is dammed to formulate Belbela reservoir. This reservoir is the main water source for more than 800 ha cultivation areas. It is known that reservoirs will lose their capacity due to sedimentation, and are therefore seriously threatened in their performance. Due to this, understanding of the quantity of soil erosion in the watershed and its deposition in the reservoir is necessary for sustainable watershed and reservoir management. The main objective of the research is to model the spatially distributed soil erosion processes in Belbela watershed in order to predict their influence on the reservoir life expectancy. It is also to assess the impact of different watershed best management practice (BMP) scenarios on sediment yield for sustainability of the reservoir. Stone lines, ploughing on contour and strip cultivation are considered as BMPs scenarios in this study. They are selected based on easiness for management by the farmers as recommended by the local agricultural office. An integrated hydrological model called Soil and Water Assessment Tool (SWAT) was used for modeling the watershed. The datasets that were used in this research are digital elevation model (DEM), land use map, soil map, weather and hydrology data. After calibration and validation of the model, the results of the model performance evaluation analysis showed well performance of the model for this study. From the sediment yield analysis, it is found that Belbela watershed generate sediments about 6.1 ton/ha/yr., which falls in high range of sediment yields. With this sediment yield, life expectancy of Belbela reservoir which was 30 years will be reduced to 23 years (reduction in 23%). It has been predicted with the simulation model the possible impact of the different BMP elements on the life expectancy of Belbela reservoir. If stone line is built (scenario-1c: reducing the farm slope length by 75%) in the agricultural areas with slope over 5%, up to 46% reduction in sediment yield can be obtained in the watershed. This method alone could improve the life of the reservoir to 43 years (an increase by 47%). Besides, on average 19% reduction of the sediment yield can be achieved simply by application of strip cultivation (scenario-3). However, ploughing on contour (scenario 2) and strip cultivation (scenario 3) conservation method will not even achieve the design period of the reservoir. Technically scenario 1c could be recommended for the watershed as best conservation measures in reducing sediment yield and increasing the life expectancy of reservoir. Nevertheless, the effect of this management option on agricultural productivity needs to be studied.

Keywords: Belbela reservoir, Sediment yield, Life expectancy of reservoir (LE), Watershed Best Management Practice (BMP), SWAT model

Introduction

Background

Soil erosion is a major factor in threatened water resource development in Ethiopian watersheds. In Ethiopia, reservoirs are considerable water source options to fulfill various types of water demands. The removal of soil from a watersheds leads to sediment accumulation in dammed reservoirs that are located in the outlet of the watershed. The siltation of small reservoirs is seen as a serious environmental threat in Ethiopia, where more than hundred dams have been built to store unevenly distributed rainwater for the dry season (Zeray et al., 2007). These reservoirs, which are essential water sources for domestic and irrigation use, are in danger of losing their function by sedimentation. Thus, an insight into soil erosion from the watershed and its deposition on reservoir is essential for reservoir management. Mitigation methods of soil erosion play a crucial role for sustainable water resource development in the watershed. More specifically, an understanding of the quantity of sediment yield from the watershed and its deposition in a reservoir as well as the alleviation methods is essential, in resolving or mitigating the troubles and for effective reservoir and watershed management.

Problem Identification

Belbela watershed is located in central highlands *of*

Ethiopia. This watershed is one of the watersheds where sediment yield is an issue for reservoir management. Due to the increasing cultivation practice, the problem of reservoir sedimentation is apparent in this watershed. The outlet of Belbela watershed is dammed to formulate Belbela reservoir (Figure 1). This reservoir is the main water source of irrigation for more than 800 ha cultivation areas. On this cultivation area, there are about 681households having an average of 6 person per house hold that relays their life on the revenue from the cultivation practice. Thus, it is visible that, as main irrigation water source, losing capacity of Belbela reservoir by sedimentation will have a huge impact on farmers' livelihoods.

Objectives and Research Questions

Main and specific objectives:

The main objective of this research is to simulate the spatially distributed soil erosion process in Belbela watershed in order to predict its influence on Belbela reservoir. The objective is also to assess the impact of different watershed management interventions on sediment yield mitigation and sustainability of the reservoir.

The Specific objectives of the research are:

- To estimate the mean annual sediment yield of the watershed under the current land management practice;
- To determine the mean annual rate of sediment deposition in the reservoir, in response to best management practice (BMP) conservation measures;
- To estimate the life expectancy of the reservoir in response to BMP conservation measures;
- To propose mitigation measures to minimize the land degradation and increase the life expectancy of the reservoir.
- *Research questions:*
- What is the current mean annual sediment yield of Belbela watershed?
- What is the estimated average annual sediment deposition rate on Belbela reservoir?
- What is the effect of BMP scenarios on mitigating the soil erosion from the watershed and life expectancy of the reservoir?
- What is technically the best management practice to mitigate the erosion problem of the watershed as well as increase the life expectancy of the reservoir?

Study Area Description

Location

The Belbela reservoir and its watershed are located in central high land of Ethiopia with average elevation of 2,300m.s.l with a total catchment area of 81km^2. The reservoir is found about 62 km from the main city of Ethiopia, Addis Ababa. The reservoir catchment area is bounded between 39^{0}00'40" - 39^{0}05'59" East longitude and 8^{0}50'07" - 8^{0}59'35" North latitude in Oromia Region, East Shoa zone under the administration of Adaa woreda. Currently the reservoir is operated by Oromiya Water Resource Authority.

Climate and hydrology

Climate (Precipitation & Temperature)

Ten years (2000 to 2009) of rainfall data and temperature data was collected from the National Meteorological Serves Agency (NMSA) of Ethiopia for three meteorological stations (i.e: Debrezeit, Chefedonsa and Mojo) that are located near the study area. The rainfall pattern of the three stations shows that, there is no significant variation in the mean annual rainfall between the stations. In these stations, high rainy seasons are observed in July and August. The monthly rainfall in the study area ranges from 19.54mm to 298.37mm. The mean monthly temperature is between 14°C and 23°C throughout the year. The hottest season extends from February to late June.

Hydrology

The Belbela watershed does not have a gauging station for measuring flow. Since Belbela watershed stream flow end up to Mojo stream, the watershed delineation has been extended till Mojo city taking Mojo gauging station as outlet for delineation of the watershed (Figure 1). This will help in obtaining flow data, which is a crucial input while calibrating the model during development process. Thus, the model will be developed for Mojo watershed and the study area (i.e. Belbela watershed) will be considered / treated as sub watershed in this research. The gauging reading of flow from this station which ranges from 2000 to 2009 was taken from Ministry of Water, Irrigation and Energy (MoWIE) of Ethiopia.

Land use and soil type

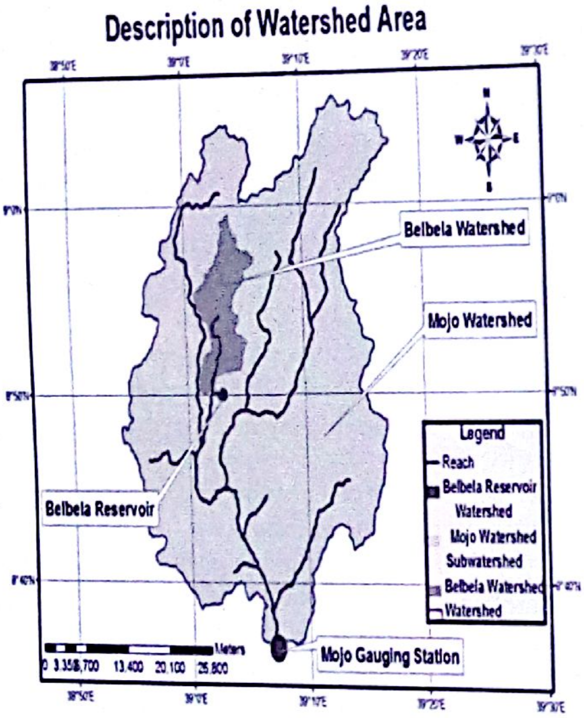
Land use

According to shape file of existing land use obtained from Oromiya Water Works Design and Supervision Enterprise (OWWDSE), the cultivation area in Belbela watershed accounts about 98.5%. The residential areas in the watershed are the second dominant land use. They account 0.6% of the watershed area. The rest 0.9% are covered with Exposed Rock Surface, Degraded Land and Pasture land.

Soil types

According to the shape file obtained from MoWIE of Ethiopia, the dominant type of soil in Belbela watersheds is vertic cambisol which cover 91% of the watersheds area. The second dominant soil type in this watershed is pellic vertisols which covers 9 % of the watershed area.

Figure 1: Description of the watersheds in the study



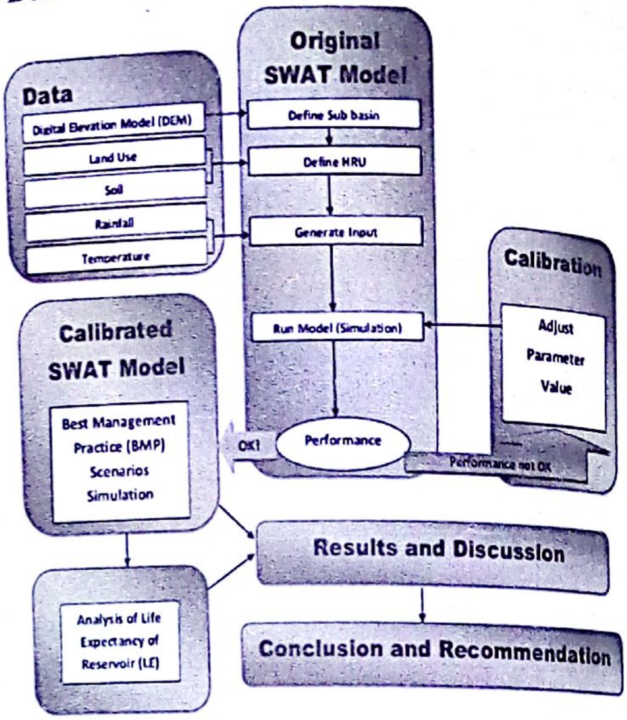
Methodology

General

The research demonstrates the estimation of sediment yield from the watershed and its effect on reservoir life expectancy. It also estimates the degree of influences of watershed management intervention in mitigating soil erosion problem of Belbela watershed. An integrated hydrological and sediment yield model called SWAT was used for modeling the watershed. The datasets that were used in this research are digital elevation model (DEM), land use map, soil map, weather data and hydrology data. The methodology includes data collection, model development, scenarios simulation, analysis of life expectancy, result & discussion, and conclusion & recommendation. Figure 2 shows the framework that has been followed in this study.

Figure 2 Frame work of the study

Best management practices Scenarios



Best Management Practices (BMPs) are combinations of practical management, cultural, and structural practices that agricultural scientists, government agencies, or other planning agencies believe to be the most effective and economical way of controlling erosion while maintaining agricultural production (Donald W.Meals et al, 2003). Accordingly, in order to choose the BMP that could be done in the watershed, a discussion has been made with the Woreda Agricultural Buro which is parts of the government and farmers in the watershed. The BMP scenarios for the study area that were selected and simulated in this study are summarized as shown in Table 1.

Sediment Yield Analysis

SWAT uses the Modified Universal Soil Loss Equation (MUSLE), an improvement of Universal Soil Loss Equation (USLE) developed by Wischmeier et al. (1965, 1978), to predict erosion by rainfall and runoff. This method uses runoff to represents energy used in detaching and transporting sediment (William, 1975).

Scenarios	Description	SWAT parameter to be revised
Sc-1	Parallel stone line: 25[a], 50[b], 75[c] % (For farm areas with slope > 5%)	HRU(.hru) input table
Sc-2	Plouhing on contour: (P=0.9)*	Mgt1 input table
Sc-3	Strip cultivation: (P=0.8)*	Mgt1 input table

a = reducing the slope length of the farm by 25% c = reducing the slope length of the farm by 75%
b = reducing the slope length of the farm by 50% * = the factors are defined for Ethiopia by Humi (1985)

$$sed = 11.8\ (Q_{surf} \times q_{peak} \times area_{hru})^{0.56} \times K_{USLE} \times C_{USLE} \times LS_{USLE} \times CFRG$$ Equation 1

Where:

sed : sediment yield/given day (metric tons)

Q_{surf}: surface runoff volume (mm H_2O/ha)

q_{peak} : peak runoff rate (m^3/s)

$area_{hru}$: area of Hydraulic Response Unit ha

K_{USLE} : USLE soil erodibility factor (0.013 metric ton m^2hr / (m^3-metric ton cm))

C_{USLE} : USLE cover & management factor

P_{USLE} : USLE support practice factor

LS_{USLE} : USLE topographic factor

CFRG : coarse fragment factor

Life Expectancy Analysis of Reservoir

The life expectancy of a reservoir is a useful parameter for assessing its sustainability as a useful component of a water resource system. It is the expected time at which the reservoir dead storage will be completely filled with sediments. According to Gebrehawrit and Haile, (1999), the life expectancy of a reservoir can be estimated by dividing the reservoir dead storage capacity by the rate of sedimentation as shown in Equation 2 below.

$$LE = \frac{RSC}{SR}$$

Equation 2

Where:

LE: Life Expectancy of the reservoir (year)

SR: Sedimentation Rate (m^3/year)

RSC: Reservoir Dead Storage Capacity (m^3)

The dead storage of the reservoir were obtained from literatures as they indicate that it was obtain from the design documentation of the dams from Oromia Irrigation Development Authority Central Branch office, 2000 Adama.

The sedimentation rate can be found by multiplying the SWAT sediment simulation outcome to trap efficiency (*TE*) of the reservoir.

There are different approaches to estimate *TE* of reservoir (e.g: Rausch and Heinemann, 1984; Verstraeten and Poesen, 2000). One of the most commonly used empirical based models is that proposed by Brown (1943), which is given in Equation 3.

$$TE = 100 \times \left[1 - \left(\frac{1}{1 + 0.0021 D \frac{C}{A}}\right)\right]$$

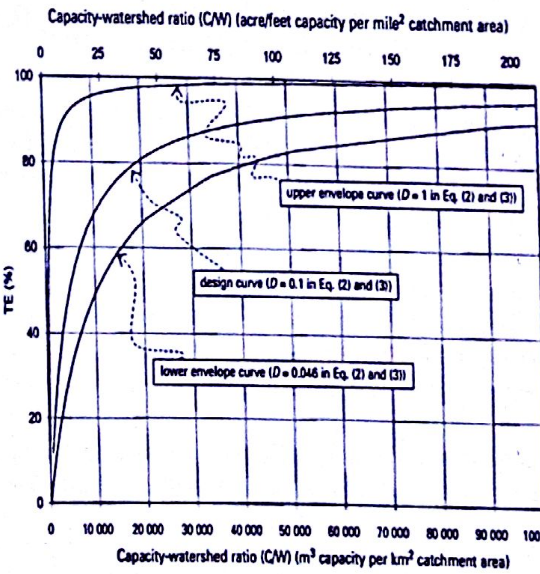
Equation 3

Where:

TE : Reservoir trap efficiency (%) *C* : Reservoir storage capacity (m3)

A : Catchment area (km2)

D : has constant value ranging from 0.046 to 1 with a mean value of 0.1 (Figure 4).



Source: Modified from 'Discussion of Sedimentation in reservoirs by J. Witzig'. Brown, C.B., Proceedings of the American Society of Civil Engineers, 1943, reproduced by permission of the American Society of Civil Engineers

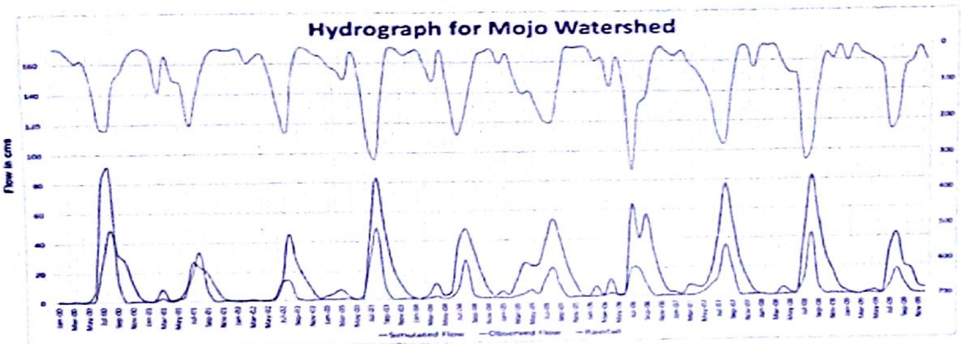
Figure 4: Trap efficiency related to capacity/watershed ratio

The value of *TE* depends on the value of *D*, which is again depends on reservoir characteristics. Brown (1943) suggested that, value for *D* is close to 1 for reservoir in regions with smaller and more variable runoff and for those that hold back and store flood flows. Since Belbela reservoir fulfills the requirements of Browns suggestion, 1 has been used for *D* to estimate the trap efficiency of the reservoir (Figure 4).

Model Results and Discussion

SWAT Model Results

The first simulation using default parameters was not able to correctly reproduce the runoff in the watershed because the model overestimates peak flow from the watershed (See Figure 5 for comparison of measured and simulated values of flow on a monthly basis). The Figure as well as the model performance evaluation shows that, the model is below the performance criteria. Therefore, parameter calibration was needed after identifying the most sensitive parameters for runoff via sensitivity analysis.



SWAT Model Sensitivity Analysis Results

The sensitivity analysis work shows that, curve number (Cn2) and threshold depth of water in the shallow aquifer required for return flow to occur (GWqmn) are the first & second sensitive parameters respectively followed by Maximum potential leaf area index (Blai), Available water capacity of soil layer (Sol_Awc) & Soil evaporation compensation factor (Esco).

SWAT Model Calibration and Validation Results

From the historic meteorological data, the total annual water yield was 126 mm. However, the simulated results in total water yield of 198mm which is over estimated. Thus a manual calibration has been done in order to meet the simulated output values to the actual annual averages. Eventough the curve number (Cn2) is found to be the most sensitive parameter in this model, since most of the watershed is used for agriculture, the range 60 - 87 for Cn2 seems to be within the range. Thus no calibration has done for it. The next parameter to be calibrated is GWqmn. The default values given for this variable is 0, which is not reasonable. Thus after some trial and error the Gwqmn is adjusted to 37 mm which results in simulated annual average water yield to 125mm. Finally the model goodness-of-fit was evaluated both on a daily and monthly basis. For calibration period (2001-2006), the model performance evaluation analysis gives PBIS -0.59%, r^2 = 0.67 and ENS = 0.52 on daily bases and PBIS 4.11%, r^2 0.72 and ENS 0.72 on monthly bases. For the calibration period, the comparison of measured and simulated value on monthly base is shown in Figure 7.

The calibrated model was then run for validation period from 2007–2009 to validate the model. The result showed that the observed and simulated daily and monthly runoff closely matches. The statistical analysis results also demonstrated reasonable agreement between the observed and simulated runoff with R^2 value of 0.88, PBIAS value of -7.73 and NSE value of 0.83 on daily base, and R^2 = 0.9, PBIAS = -7.74 and NSE = 0.87 on monthly bases. For the validation period 2007-2009, the comparison of measured and simulated value

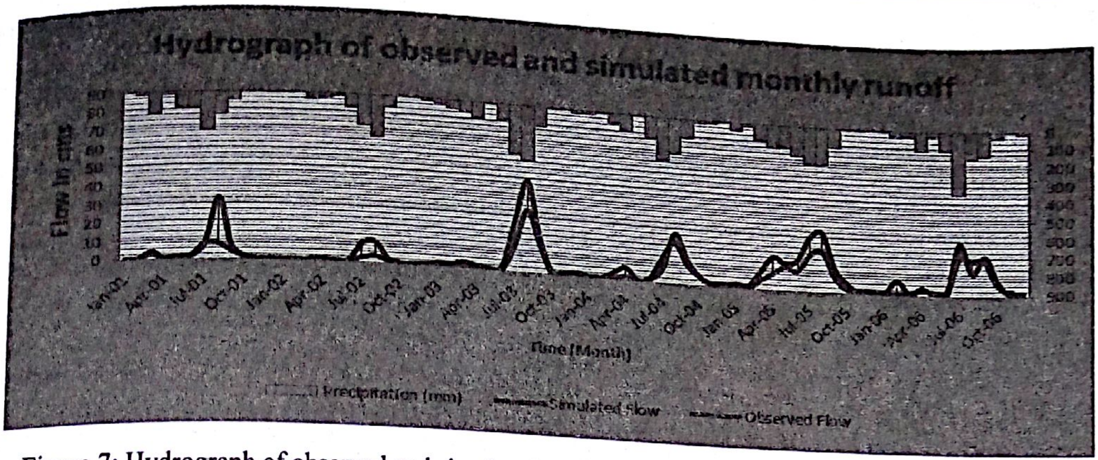


Figure 7: Hydrograph of observed and simulated monthly runoff for the calibration period 2001-2006

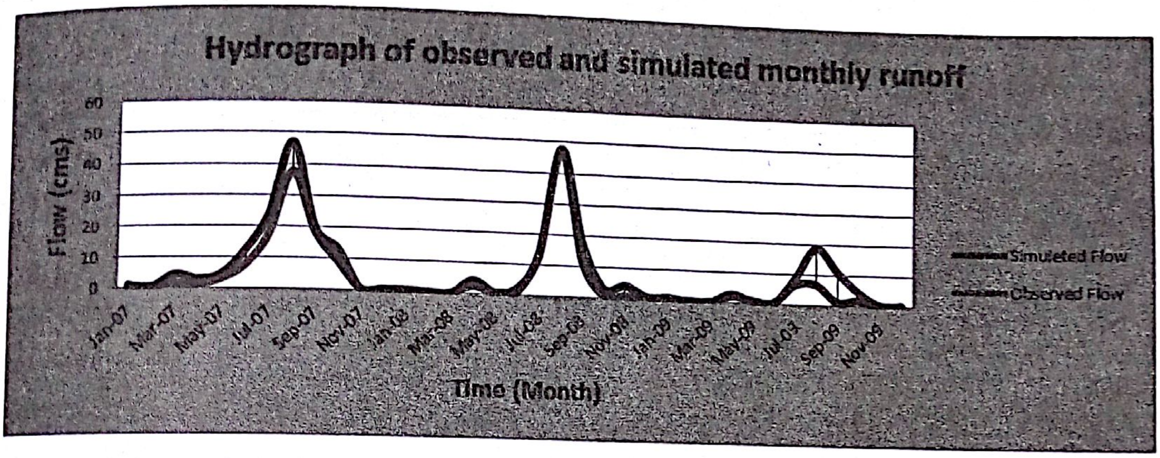


Fig-
Hy-
ure 8:

SWAT Model Sediment Result

In this research, due to unavailability of sediment data, the model couldn't be validate for sediment yield. Thus, the simulated sediment data after the calibration and validation of flow is used. It is found that, with the current condition, the average annual sediment load of Belbela watershed is 28,270m^3 (i.e. 6.1 ton/ha/year). According to N.O Carvalho et al. 2000, high values of sediment production, such as 200t/km/year (2ton/ha/year), are very prejudicial and may come to affect the reservoir with undesired deposits. N.O Carvalho et al. 2000 also say that, the values reported in Table 2 may be used as indicators for surveys of degree of sediment production.

Table 2: Acceptable values for sediment production

Tolerance	Sediment Yield		
	ton/mi2/ yr	ton/km2/ yr	ton/ha/yr
High	>500	175	>1.75
Moderate	200 - 500	70 - 175	0.7 - 1.75
Low	<100	35	0.35

Source: N.O Carvalho et al., 2000

Therefore, the sediment yield from the Belbela watershed falls in high range of sediment yields which will affect the reservoir with undesired deposits of sediments.

Sediment Results as response to Watershed Management Scenarios

G.D. Betrie (2011) says that, Catchment management intervention involves introducing best management practices (BMPs) to reduce soil erosion and sediment transport. Accordingly, after simulating the scenarios in the calibrated and validated SWAT model, a higher reduction of sediment yield from the watershed is obtained by reducing the slope length of the farm by 75% with a stone line conservation measures (scenario 1c). This approach can decline the sediment yield of the watershed by 46%. Strip cultivation (scenario 3) shows 19% reduction of the sediment yield from the watershed whereas plouhing on contour reduce it by 11% (scenario2). Table 3 summarized response of BMP scenarios to sediment yield.

Results on Life Expectancy Analysis of Reservoir

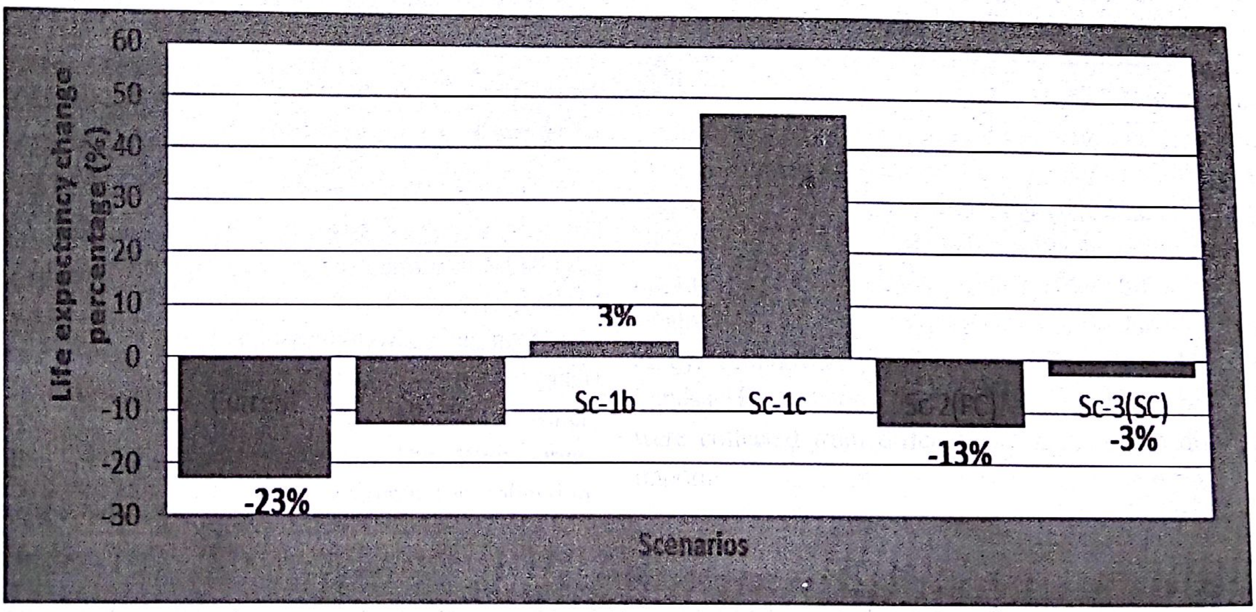
The dead storage capacity of Belbela reservoir and the sediment rate per year of its watershed should be known for the life expectancy analysis of the reservoir. In view of that, the dead storage of Belbela reservoir is found to be 0.67M m^3 (W. Totoba, 2006 and R. Deribe, 2008) and the sediment rate of the watershed is shown in Table 3.

As it shown from Figure 9, the life expectancy of Belbela reservoir can be increased by 47 % if the slope length of agricultural areas with slope greater than 6% has been reduced by 75% (scenario 1c). Reduction of the farm slope length by 50 % (scenario 1b) can also achieve the design period of the reservoir. However, plouhing on contour (scenario 2) and Strip cultivation (scenario 3) conservation method will not even achieve the design period of the reservoir.

Table 3: Life expectancy and average sediment deposition rate of Belbela reservoir

Scenarios		Sediment rate per ha (1)	Water-shed Area (2)	Reservoir Trap Efficien-cy (3)	Sediment rate (4)	Life Expectancy (5)
		(m^3/ha/year)	(ha)	(%)	(m^3/year)	(Years)
Current condition		3.7	8012	95	28270	23
Sc-1 (Stone line)	25% a	3.4	8012	95	25900	26
	50% b	2.8	8012	95	21320	31
	75% c	2.0	8012	95	15230	44
Sc-2 (Plouhing on con-tour)		3.3	8012	95	25120	26
Sc-3 (Strip cultivation)		3.0	8012	95	22840	29

a = reducing the slope length by 25% b = reducing the slope length by 50% c = reducing the slope length by 75% Column 1= Obtained from SWAT result Column 3= Equation 2 Column 4 = Column 1*2*3 Column 5= Equation 1



a = reducing the slope length by 25% b = reducing the slope length by 50% c = reducing the slope length by 75%
PC = Plouhing on contour SC = Strip Cultivation

Figure 9: Life Expectancy increment percentage as response to BMP scenario

Summary of result

The results of this research analysis as response to the research question are summarized as shown in Table 4.

Table 4: Summary of the research analysis result

No	Research Questions	Scenarios		Results S.Y	Results L.E
1	What is the current estimated average annual sediment yield of Belbela watershed?	Current condition		6.1 (ton/ha/year) or 630mm/yr	
2	What is the estimated average annual sediment deposition rate on Belbela reservoir?	Current condition		28,270 (m^3/year)	23 (year)
				Change Percentage of S.Y (%)	Change Percentage of L.E (%)
3	What is the effect of BMP scenarios on mitigating the soil erosion from the watershed and their effect on life expectancy of the reservoir?	SC1 - Stone line	a	7	-13
			b	23	3
			c	46	47
		SC2 -Ploughing on Contour		9	-13
		SC3-Strip Cultivation		19	-3
4	What is technically the best management practice to mitigate the erosion problem of the watershed?	Reducing the farm slope length by 75% with stone line.			

a = reducing the slope length by 25% b = reducing the slope length by 50% c = reducing the slope length by 75%

S.Y= sediment yield **L.E= life expectancy of reservoir**

Conclusion and Recommendation

In general it is observed that reducing the farm slope length by 75% (scenario 1-c) shows the best result as compared with the rest scenarios, in reducing the sediment yield and increase the life expectancy of the reservoir. Thus technically it could be recommended for the watershed as best conservation measures. Nevertheless, this study has not incorporated the response of the BMP options to agricultural productivity in the area. Thus, it is recommended if a study done on the effect of this management option on agricultural productivity.

Currently Belbela reservoir design period is over. However, still it is working as a main irrigation water source with high maintenance cost like flashing the sediments out from the outlet of the dam. This maintenance method causes sedimentation problem in the conveyance and distribution channel in the downstream. Because of that, there are complains of water shortage from the downstream farmers. According to the information obtained from the Woreda Agricultural Buro, they are planning to construct a new dam about 400m above the inlet of Belbela reservoir to overcome the problem of irrigation water shortage. Thus, this research could be recommended as a vital input for the new reservoir and its watershed management regarding sediments and life expectancy analysis of reservoir.

References

Brown, C.B.: Discussion of Sedimentation in reservoirs, by J. Witzig. Transactions of the American Society of Civil Engineers 69, 1493-1500, 1943.

R. Deribe: Institutional Analysis of Water Management on Communal Irrigation Systems: The Case of Atsbi Wemberta District in Tigray Region and Ada'a District in Oromiya Region , Ethiopia, Addis Ababa University, 2008.

G.D. Betrie et al.: Sediment management modelling in the Blue Nile Basin, Hydrol.Earth Syst.,15,807, 2011.

Gebrehawariat, G., Haile. H.: Reservoir Sedimentation Survey Conducted on Four micro dams inTigray, Commission for Sustainable Agriculture and Environmental Rehabilitation in Tigray, Ethiopia, 1999.

Hurni,H: Soil conservation manual for Ethiopia,Ministry of Agriculture. Addis Ababa, Ethiopia, 1985.

Donald W. Meals: A farmer's Guide to agriculture and Water Quality Issues: Erosion and Sediment Control Fact Sheets: BMPs for Erosion Control, USDA-CSREES:USEPA'S National Agriculture Compliance Assistance Centre and North Carolina State University Cooperation Extension, 2003.

N.O Carvalho et al.; Reservoir sedimentation assessment guideline, ANEEL/SIH, 2000

Rausch, D. L. and Heinemann, H. G.: Measurement of reservoir sedimentation: Erosion and sediment yield: Some Methods of Measurement and Modelling, Geobooks, pp. 179 -200, 1984.

Totoba, Wakena: Operational Analysis of theWadecha-Belbela Reservoir System (Ada'a Liben Woreda , in Oromia Region) Wadecha-Belbela Reservoir System, Arba Minch Univerisity, 2006.

Verstraeten,G.&Poesen, J: Estimating trap efficiency of small reservoirs and ponds: methods and implications for the assessment of sediment yield. Progress in Physical Geography 24(2), 219-251., 2000.

Williams, J.R: Sediment-yield prediction with universal equation using runoff energy factor, 1975.

Zeray, L., Roehrig, J. and Chekol, D.A: Climate Change Impact on Lake Ziway Watershed Water Availability, Ethiopia: FWU Water Resources Publications. Volume No: 06/2007. ISSN No. 1613-1045.pp 18-23, 2007.

Seasonal Stream flow Variability Analysis and Forecasting, Lake Tana Sub-Basin, Upper Blue Nile Basin, Ethiopia

Mengistu A. Jemberie[1], Adane A.Hawas[2]

[1]Department of Civil Engineering, Adama Science and Technology University, P.O.Box1888, Adama, Ethiopia, Email: mngst_addis@yahoo.com Phone: +251913715883

[2]Department of Hydraulics and Water Resources engineering, Arba Minch University, Institute of Technology, Arba Minch, Ethiopia, Email: adaneabie@ethio.net Phone: +251911544432

ABSTRACT

In this paper seasonal rainfall-runoff variability analysis is detected and streamflow is forecasted using stochastic approach for Lake Tana Sub basin of Abbay River Basin which is located at the high land areas with one rainy season within a year and having high spatial and temporal variation of rainfall and runoff.

The seasonal stream flow variability analysis of the basin is done from the existing and recorded meteorological and hydrological data. The four major seasons of the year are taken for seasonality analysis (i.e. Winter (JFM), Spring (AMJ), Summer (JAS) and Autumn (OND)). The rainfall variability is analyzed using seasonality and variability measures of CV, SRRD and SRI. The rain fall variability is higher related to altitude than latitude and longitude. From the four seasons there is no significant variation and trend spatially as well as temporally.

The seasonal runoff and streamflow variation is analyzed using HEC-HMS hydrological model to generate runoffs at required and selected points to detect the spatial variation. The gauged stations and catchments are easily analyzed from recorded time series streamflow data. Runoff coefficient is taken as a variability measure for both generated and recorded stream flows. The runoff coefficient ranges from 0 to 1. The range is high at dry seasons and less at wet seasons. The average runoff coefficient vale of the basin is obtained as 0.28 in which the value ranging from 0.18 to 0.36 at dry and wet seasons. The average SRC value from generated runoffs is 0.45 at which it is 0.3 at dry and 0.6 at wet seasons. Runoff coefficient is more dependent on antecedent soil wetness condition. Seasonal streamflow is forecasted using PARMA (p, q) and MPAR (p) models.

Key Words: Lake Tana Basin, Seasonal Variability, CV, HEC-HMS, Runoff Coefficient, streamflow, PARMA (p, q), MPAR (p).

Introduction

Background

Globally, there is growing concern that natural and anthropogenic climate changes are intensifying the hydrological cycle, which may be expected to influence river flow regimes (Harvey et al., 2010). Since there is seasonal variation of climate it is unquestionable that there will be also seasonal variation of both meteorological and hydrological variables. Stream flow variability is highly dependent on rainfall variability. Such variability occurs temporally as well as spatially. The temporal variability occurs at many time scales , from hourly to daily, from daily to monthly, from monthly to seasonally and from seasonal to inter-annual and beyond. The spatial variation also occurs from local to regional, from regional to country and from country to continental.

Whether it is natural or artificial reservoir, the seasonal flow variation affects its storage as well as the supply and demand. Knowing Seasonal flow variability and forecasting of hydrological variables potentially improves water management (Brown *et al.*, 2006). The seasonal variability of flow and stage (Lake surface level) are factors which play the major role on the natural flow of the rivers. Considering high flow and low flow seasons and the variabilities in the derivation of reservoir operating rules is essential for coordinating the relationship between flood prevention and benefit.

Generally Lake Tana sub-basin is characterized by enormous potential for development of irrigated agriculture, hydropower, tourism, bio-diversity and recreations. For this reason, it is one of the richest sub-basin concerning water resource (Daniel et al., 2007). Since there is seasonal variation of hydro meteorological variables, there is fluctuation of the lake level. The lake as a reservoir regulates the seasonal flow variations at the Chara Chara weir site for the purpose of proposed and constructed projects. For example the Tana Beles Transfer uses the regulated excess water from the lake.

Location and Accessibility

Lake Tana basin is situated on the north western plateau of Ethiopia at the head waters of the Abay River basin, in the Amhara administrative regional state. Its geographical location extends from 10°57'N to 12°47'N latitude and from 36°53'E to 38°15'E longitude. The basin area is 15,321km^2 from which around 20% of it is the lake (Zewdie *et al.*, 2010). The basin is also divided to four main sub basins namely; Gilgel Abay, Gumara, Ribb and Megech.

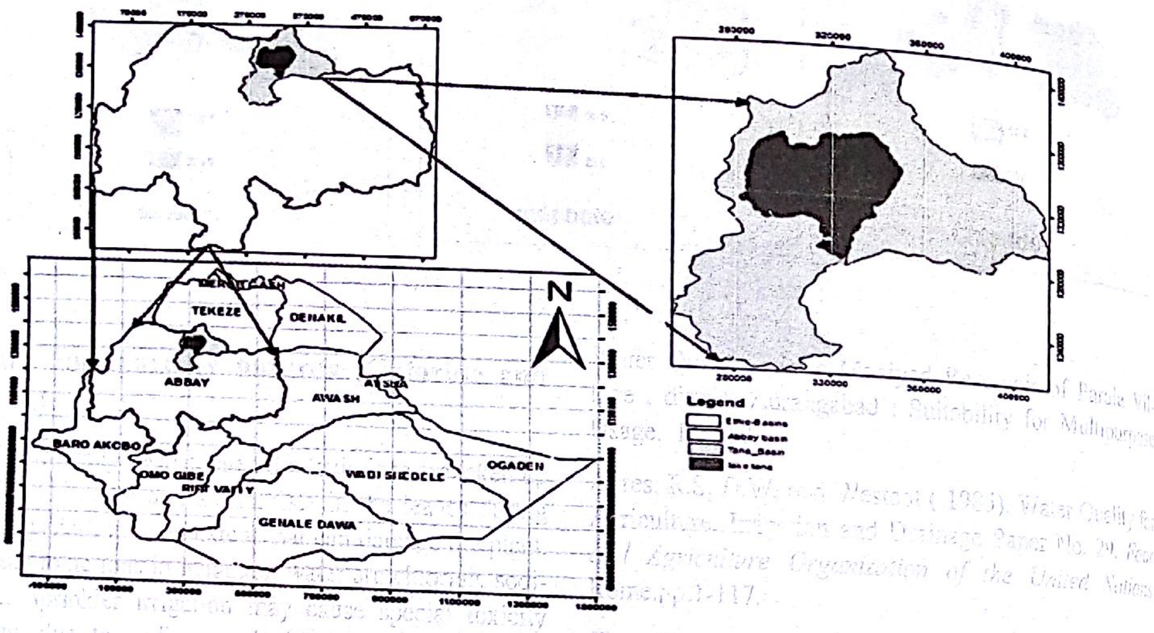


Figure 1.1 Location of Study Area

Methodology and Analysis

Seasonal Rainfall variability analysis

To analyze the spatial and temporal seasonal rainfall variation, we used statistical and empirical measures. From the recorded rainfall, we have precipitation data of 12 stations. Areal precipitation is taken using thiessen polygon method for each precipitation station.

Coefficient of Variation

Coefficient of Variation is one of the statistical measures of variability which can be used for any hydrological time series variables and others. It is the ratio of standard deviation to the mean of time series data.

$$cv_\tau = s_\tau / \bar{y}_\tau \quad \text{......................... (4.1)}$$

Where, cv_τ is Seasonal Coefficient of Variation

s_τ is Seasonal Standard Deviation and

$\bar{y}_\tau$ is Seasonal Mean

Seasonal Relative Rainy Days

It is the ratio of rainy days within the season to the total number of days in the season. It shows the variation of wet and dry days within seasons spatially as well as temporally.

$$\text{SRRD} = \frac{n}{N} * 100 \quad \text{.................. (4.2)}$$

Where; SRRD is Seasonal Relative Rainy Days in %

N is total no of days in the season and n is the number of rainy days with in the season

Seasonal Rainfall Intensity

It is the ratio of cumulative seasonal rainfall to that of the number of rainy days with in that season. It indicates the spatial and temporal rainfall intensity variation of different seasons.

$$SRI = \frac{CSP}{n} \qquad \text{.................. (4.3)}$$

Where; SRI is Seasonal Rainfall Intensity (in mm/day)

CSP is Cumulative Seasonal Precipitation and (in mm) and

n is the number of rainy days with in the season (in day)

Seasonal flow Variability analysis

Seasonal flow variability analysis is done using Seasonal Runoff Coefficient as a measure which is simply the ratio of excess runoff to precipitation (Daniele Norbiato *et al.*, 2009). To know the excess runoffs, the base flows are subtracted from recorded flow data for gauged stations.

Seasonal Runoff Coefficient (SRC)

Runoff coefficient is one measure or index to show the spatio-temporal runoff variability. This coefficient is used mostly to estimate the runoff on the data scarce places using an empirical formula of rational method.

$$SRC = \frac{\sum Q_{sd}}{Pscp * A} \qquad \text{......................... (4.4)}$$

Where,

SRC is Seasonal Runoff Coefficint

$\sum Q_{sd}$ is Seasonal Cummulative direct runoff

Pscp is Seasonal Cummulative Precipitation and

A is the Catchment Area

Seasonal Flow Forecasting

In this research stochastic time series seasonal forecast models have been selected from SAMS2007 package (O. G. B. Sveinsson *et al.*, 2007). The model is used to forecast both stationary and non-stationary time series data. From the data quality results (non stationarity), models to forecast non-stationary time series data are selected. Seasonal forecast models such as Univariate PARMA (p, q) and Multivariate PAR (MPAR) are models which are adopted to forecast seasonal time series data.

Results and Discussion

Seasonal Rainfall – Runoff Variability

Rainfall Variability

According to the country's geographical classification the seasons are classified in to four which account three months each. Thus are: Winter (January, February & March); Spring (April, May & June); Summer (July, August & September) and Autumn (October, November & December).

The variability analysis based on variability measures of CV, SRRD and SRI is resulted along altitude, longitude and latitude as spaces and the time from 1997-2005 years. As it is shown from figure5.1, there is significant coefficient of variability variation on all seasons based on CV values and their ranges. The CV value generally ranges from 0.85 to 7.76 at Summer and Winter seasons respectively. There is high variation at Autumn season which ranges from 2.35-6.22 and less variation at Summer ranging from 0.85-1.5. The rainfall coefficient of variability is relatively higher near Lake Tana.

The rainfall variation based on SRI on the altitude, Latitude and Longitude is not significant at Winter season except some events with high SRI values and the variation is significant on the rest of seasons even though the variation range is less. The SRI ranges from 0 to 50mm/day. The range is high at Winter and low at Summer seasons. There is no visible temporal trend of SRI variation.

There is significant SRRD variation at high altitudes especially above 2300m for all seasons. There is high spatial variation than that of temporal variation. There is an increasing trend of rainy days on winter season and a decreasing trend on the spring season.

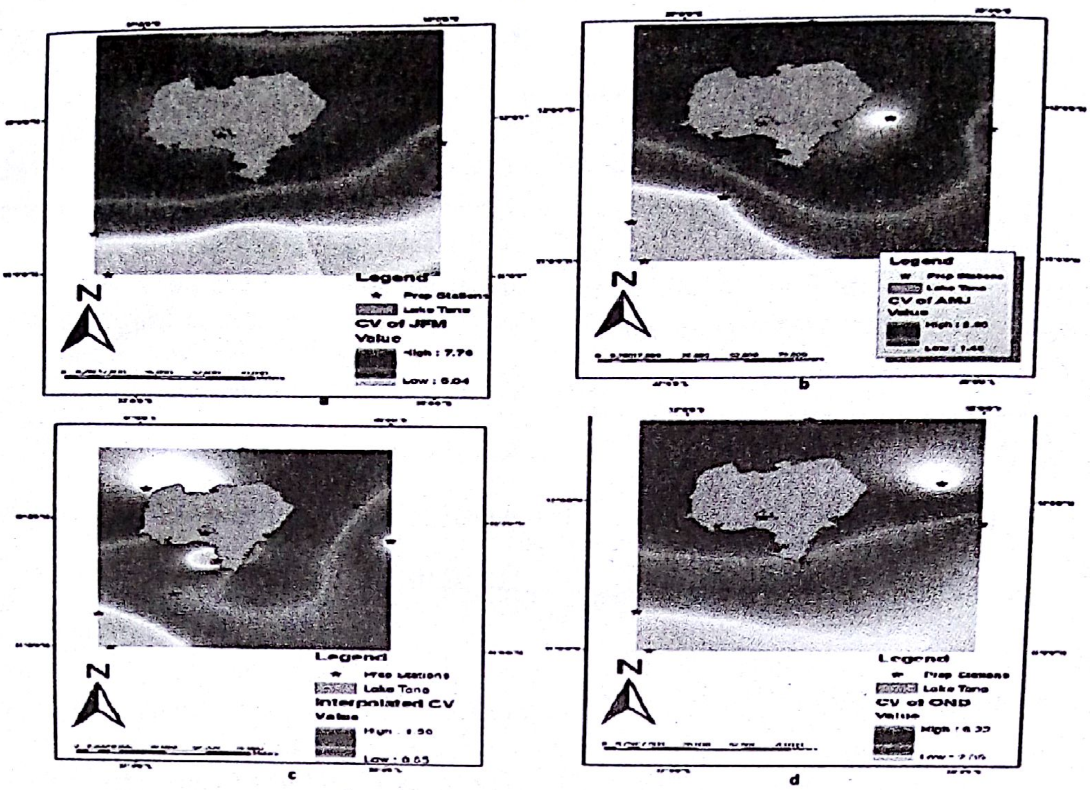


Figure 3.1 Spatial Rainfall Variability based on CV for: Winter, Spring, Summer and Autumn seasons (a, b, c and d) respectively.

As it is shown from the results, there is high variation and increasing trend of SRRD along the altitude but not that of SRI. This indicates that the areas at high altitude get more rainy days than that of low areas and the intensity of rainfall is relatively higher at low land areas than high land areas.

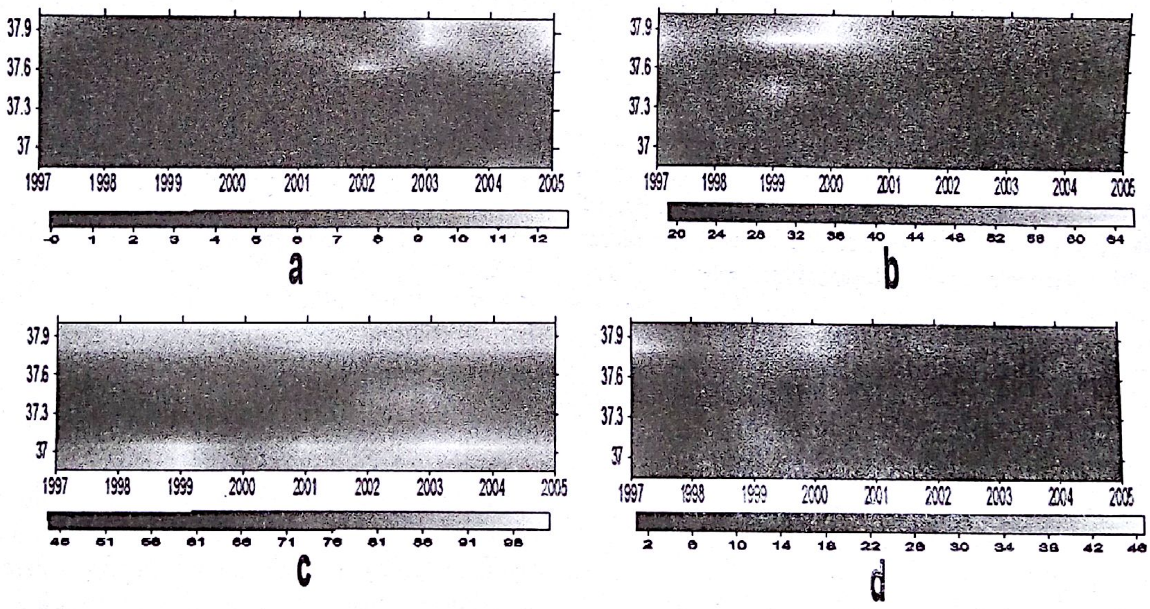


Figure 3.2 SRRD Variation along the Longitude for Winter(a),spring(b),summer(c) and autumn(d) seasons from 1997-2005.

As it is observed from Figures5.3, there is increasing temporal trend of SRRD on winter and summer seasons but a decreasing trend of on spring and autumn seasons. There is relatively high SRRD value at high Latitude and Longitudes. At summer season, number of rainy days are increased at low and high longitudes. There is high correlation between CV and SRRD. It is the number of rainy days that causes significant variation of CV than the rainfall intensity.

Runoff Variability Analysis Results

For gauged catchments the seasonal streamflow variability is easily manipulated from recorded flow data. For catchments outside gauging stations, excess runoff is generated using HEC-HMS model for selected points after the model is calibrated and validated at gauged stations. The R^2 value during the calibration period is 0.76 and is 0.68 during the validation period. Since our purpose of HEC-HMS model is to generate runoff the values are accepted.

The spatial SRC variation along the altitude, latitude and longitude is highly dependent and correlated to the SRI. As we have seen from the above figures, it is clear that all rainy days didn't give excess runoff. In other words the excess runoff is the result of infiltration excess rainfall which is the result of intensive rainfall or Antecedent Moisture Condition (AMC) of the surface. This runoff coefficient variation and distribution likely reflects the variability of the storms analyzed, mostly in terms of total precipitation, rainfall duration, rainfall intensity and antecedent wetness conditions (D. Penna *et al.*, 2011). He finally obtained runoff coefficient ranging from 0.02-0.69 with an average value of 0.15.

From generated excess runoffs the average runoff coefficient value is 0.45 which is ranging from 0.28 at winter season and 0.64 at autumn season.

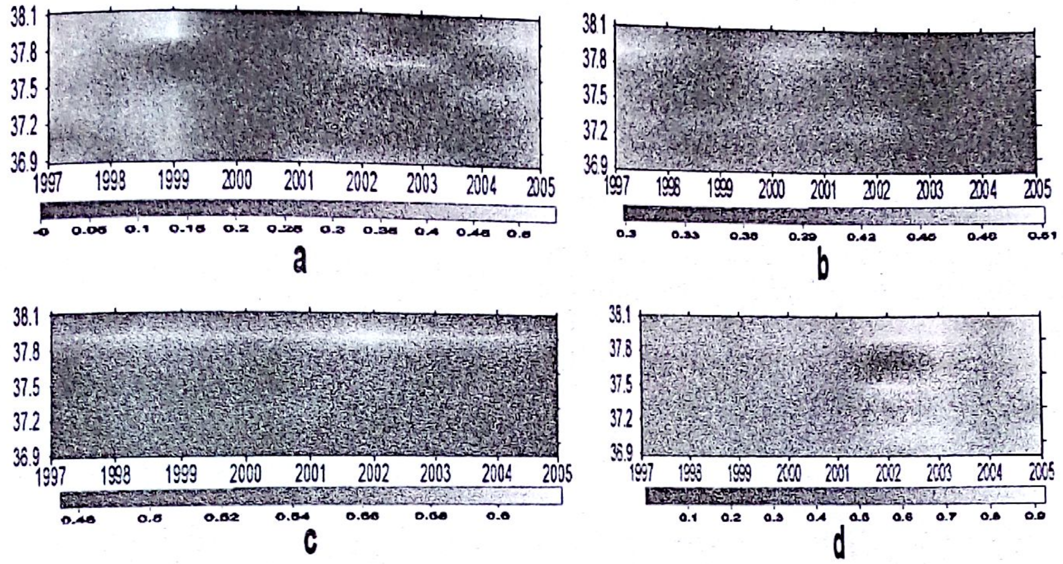


Figure 3.3 Longitudinal Runoff Variation of selected runoff sites from 1997-2005 based on SRC measure for Winter, Spring, Summer and Autumn Seasons (a, b, c and d respectively)

The range of SRC variation for both gauged and ungauged sites is high at spring and autumn seasons and low at summer season. But the average value is higher at summer and autumn seasons as a result of high runoff and erosion of the summer season and high antecedent soil moisture condition of autumn season from high summer precipitation. In addition high base flow components which are considered as runoffs have significant effect for increased SRC values.

Even though the range is very high, the average runoff coefficient value for the basin is 0.28 from recorded historical flow data and it is 0.45 from generated excess runoffs using HEC-HMS model. From both values the average of 0.36 lies on the range of theoretical and practical values used in rational method. SRC exceeds 1 at some places and some events which indicate that there was high runoff and erosion problem at that time of specific place including its upstream.

The spatial SRC variation is relatively higher at altitudes from 2200m to2400m. Generally, the areas on south East and East of the basin have higher runoff coefficient. The range and average runoff coefficient values are consistent with those values used for different soil groups and land uses.

Catchment Classification

Using SRC as a classification measure, the catchments can be seasonally classified and grouped based on their seasonal runoff coefficient values. The Catchments with high SRC values implicate that these areas are severely affected by erosion and sedimentation. Whereas areas with low SRC are areas with less erosion due to good water shed management practices or due to their soil type.

From previous studies (Shimelis G. Setegn *et al.*, 2008) has identified the erosion prone areas on the catchment and the factors using SWAT hydrological model for different scenario. According to his result, the factors for erosion are: slope factor which is known to be the main driving force for the movement of surface water. Steeper and longer slopes result in high erosion rates. The second criterion is the land cover which controls the detachability and transport of soil particles and infiltration of water into the soil. The types of the soil also play a significant role for erosion depending upon their physical properties and sensitivity to erosion. As it is shown from the figures below, the runoff coefficient is high on the areas relatively higher altitudes and slope.

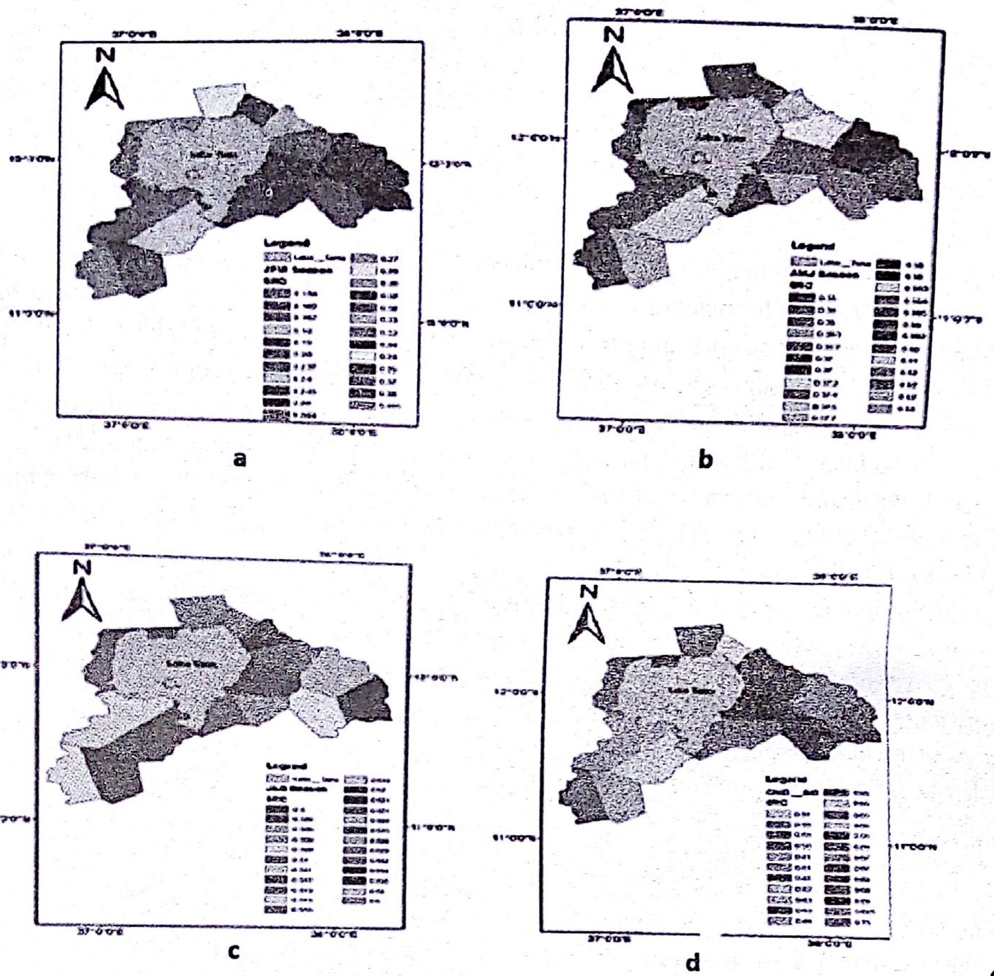


Figure 3.4 Classified Catchments based on SRC variation results of generated runoff sites for: Winter, Spring, Summer and Autumn seasons (a, b, c and d) respectively.

Seasonal Flow Forecasting

From the results of SAMS2007 model output, PARMA (1, 2), PARMA (2, 1) and PARMA (2, 2) univariate models are better than MPAR (p) to estimate the volume. Estimation of peak flows and their timing using both PARMA (p, q) and MPAR (p) is worth except for summer season. MPAR (p) is better than PARMA (p, q) to estimate peaks and base flows. MPAR (2) and MPAR (3) estimate the peak better than others for summer season.

If the volume is the criterion for streamflow prediction, PARMA (2, 0) for winter; PARMA (2, 2) for spring; PARMA (2, 1) for summer and MPAR (2) for autumn seasons can give good results than others. MPAR (p) model is better than PARMA (p, q) to estimate peak and minimum flows of summer season that gave R^2 of 0.786 and MLE of -0.055. But it is not best model to estimate timing and volume.

From the literatures it is proposed to use higher order PARMA (p, q) models to forecast seasonal flows. But from the result of this research, higher order PARMA (p, q) models have limitation to forecast all flow types. The model efficiency may also vary according to the seasonal streamflow data quality. Thus it is not possible to generalize that PARMA (p, q) and MPAR (p) models are best models for seasonal time series data except volumes and base flows.

Conclusion

Even though the basin is relatively getting different rainfall amounts and have also different distribution pattern, there is slight spatial and temporal variation except some events and places. There is high rainfall amount greater than 50% of annual precipitation at the summer season (25% of the year). From the results and discussions above, we can conclude that the rain fall variability is highly dependent on altitude and the lake. The coefficient of rainfall variability is highly dependent on number of rainy days weather its intensity is high or less. From the results obtained we can conclude that Lake Tana has slight effect on seasonal rainfall variation based on CV and altitude has significant impact to seasonal rainfall variation than latitude and longitudes.

Seasonal Runoff variation is more influenced by runoff intensity than rainfall duration and number of rainy days. Runoff coefficient is more influenced by rainfall intensity, antecedent moisture condition and erosion (upstream erosion and downstream sedimentation).

From the results obtained we can conclude that coefficient of variation has limitations at places of highly exposed to erosion problems in which its value is greater than 1 that indicates erosion and siltation. Runoff coefficient value should be clearly set for urban (impervious) and areas with different perviousness characteristics with erosion. From the range of runoff coefficient values, most of the areas in the basin are homogenous at summer season than other seasons. From hydrological data quality tests, it is clearly observed that seasonal time series data are not homogeneous, stationary and independent. Minimum flows are better stationary and homogeneous than mean and maximum flows.

It is not possible to generalize that SAMS2007 model is best model or not to forecast future streamflows. For Lake Tana basin, PARMA (p, q) model is better for volume estimation which is vital for reservoir planning and management. And it is worth for peak flow estimation and timing. MPAR (p) model is also better for base flow (low flow) and summer season streamflow estimation. It is also better than PARMA to estimate peaks without considering the timing. To estimate future drought seasons and floods not considering the timings, MPAR is better. Thus decision makers and researchers can use the two models according to the purpose of future water resource.

References

Abrahart, R. S. (2000). Comparing neural network and autoregressive moving average techniques for the provision of continuous river flow forecasts in two contrasting catchments. *Hydrological Process* , 14, 2157-2172.

Abreham, A. (2009). *Open water Evaporation Estimation Using Ground Measurements and Sattelite Remote Sensing: Acase study of Lake Tana, Ethiopia.*

Andrea Števková, S. K. (2010). *Seasonality Analysis of the Pooling of Winter Low Flows on the Territory of Slovakia.* Bratislava, Slovakia.

Astatkie, T. W. (1997). Nested treshold autoregressive (NeTAR). *Forecasting* , 13(1), 105-116.

Awlachew, E. S. (2009). *Improved Water and Land Management in the Ethiopian Highlands: Its Impact on Downstream Stakeholders Dependent on the Blue Nile.* IWMI .

Awudallah AG., R. J. (2000). Improving Forecasts of Nile Flood using SST inputs in TFN Model. *Hydrological Engineering* , 5(4), 371-379.

Awulachew, A. D. (2009). *Characterization and Atlas of the Blue Nile Basin and its Sub basins* . IWMI.

A.Ramachandra Rao, Khaled H. Hamed (2000). Flood Frequency Analysis.

Bernhofer, C. R. (2011). Long term variability of the annual hydrological regime and sensitivity to temperature phase shifts. *Journal of Hydrology and Earth system Science* .

Bollerslev, T. (1986). Generalized Autoregressive Conditional Hetroscedasticity. *Econometrics* , 31, 307-327.

Bracken, C. W. (2009). *Seasonal to Inter-Annual Streamflow Simulation and Forecasting on the Upper Colorado River Basin and Implications forWater Resources Management.*

Burn, D. (1997). Catchment similarity for regional flood frequency analysis using seasonality measures. *Hydrology* , 202, 212-230.

Daniele Norbiato, M. B. (2009). Controls on event runoff coefficients in the eastern Italian Alps. *Journal of Hydrology* , 312–325.

Engle, R. (1982). *Autoregressive conditional hetroscedasticity with estimates of the variance of UK inflation.* UK.

Gebremariam, H. (2009). *Assessment of climate change impact on the net basin supply of Lake Tana water balance.*

Graham, S. B. (2009). *A comparison of storm-based and annual-based indices of hydrologic variability: a case*

Gudmundsson, L. T. (2011). *Projected changes in future runoff variability - a multi model analysis using the A2 emission scenario.* Oslo: WACH.

Harvey, J. H. (2010). *UK seasonal river flow variability in near-natural catchments, regional outflows and long hydrometric records.* Center of Ecology and Hydrology.

Henley, B. M. (2007). *Seasonal Stochastic Rainfall Modelling Using Climate Indices: A Bayesian Hierarchical Model.*

Hipel, K. M. (1994). *Time series modeling of water resources and environmental systems.* Amsterdam: Elsvier.

Hyun-Han Kwon, C. B. (2009). *Seasonal and annual maximum streamflow forecasting using climate information: application to the Three Gorges Dam in the Yangtze River basin, China.*

Jong-Suk Kim, S. J. (2010). *Streamflow variability and hydroclimatic change at the Bear Brook Watershed in Maine (BBWM).* USA: Environmental Monitoring Assessment.

K.A. Assefa, S. A. (2008). *Flood Forecasting and Early Warning in Lake Tana Sub Basin, Upper Blue Nile, Ethiopia .* UNESCO-IHE: WaterMill.

Kebede, S. Y. (2006). Water balance of Lake Tana and its sensitivity to fluctuations in rainfall, Blue Nile basin, Ethiopia. *Hydrology* , 316, 233-247.

Kuo I.T., S. Y. (1993). An intervention model for average 10 day streamflow forecast and synthesis. *Hydrology* , 151, 35-56.

Lane, W. a. (1990). *Applied Stochastic Techniques, personal computer version 5.2, users manual.* Denver, Colorado: Bureau of Reclamation.

Lettenmaier, S. S. (2011). Seasonal hydrologic prediction in the United States: understanding the role of initial hydrologic conditions and seasonal climate forecast skill. *Hydrol. Earth Syst. Sci.* , 15, 3529–3538.

Livna, V. A. (2003). *A stochastic model of river discharge fluctuations.*

Lu, H. S. (1996). *Research on Long-term runoff forecasting for Danjiangkou reservoir.*

Mcleod, A. H. (1977). *Advances in Box-Jenkins Modeling 2. Applications.*

Merz, R. B. (2006). Spatio-temporal variability of event runoff coefficients. *Journal of Hydrology* , 331, 591–604.

Michael B. Smith, V. I.-J. (2004). Runoff response to spatial variability in precipitation: an analysis of observed data. *Hydrology* , 267-286.

Montanari, A. R. (2000). *A Seasonal Fractional ARIMA model applied to the Nile Miver monthly at Aswan.* Water Resources Research.

Mugabe, F. H. (2004). *Spatio-Temporal Rainfall and Run-off Variability of The Runde Catchment, Zimbabwe, and Implications on Surface Water Resources.* African Water journal.

Norbiato, D. B. (2009). Controls on event runoff coefficients in the eastern Italian Alps. *Journal of Hydrology* , 375, 312–325.

O. G. B. Sveinsson, J. D. (2007). *Stochastic Analysis, Modeling, and Simulation (SAMS) Version 2007 USER's MANUAL.* Fort Collins, Colorado : Colorado State University.

Olden, J. D. (2003). *Redundancy and the choice of hydrologic indices for characterizing stream flow regimes.* River Research and Application.

Ooms, M. F. (2001). *A Seasonal periodic long memory model for monthly river flows.* Environmental modeling & Software.

Pardé, M. (1920). *Le régime des cours d'eau en Suisse. Revue de géographie alpin.*

R. Ley, M. C. (2011). Catchment classification by runoff behaviour with self-organizing maps (SOM). *Hydrology and Earth System Sciences* , 15, 2947–2962.

Rosso, C. D. (2002). A multi-level approach to flood frequency regionalisation. *Hydrology and Earth System Sciences* , 185-194.

S. Kebede, Y. T. (2005). Water balance of Lake Tana and its sensitivity to fluctuations in rainfall, Blue Nile basin, Ethiopia. *Journal of Hydrology* , 316- 233–247.

S., B. M. (1994). *Time Series Modeling for Long-Range Stream- Flow Forecasting.* Water Res.Plan. Manag.

Salas, J. (1993). *Analysis and Modeling of Hydrologic Time Series, Handbook of Hydrology.* New York.

Salas, J. (1993). *Analysis and Modelling of hydrological time series.* New York.

Salas, J. D. (1980). *Applied Modeling of Hydrologic Time Series.* Littleton, CO, USA: Water Resources Publications.

Setegn, G. (2006). *Hydrological and Sediment Yield Modelling in Lake Tana Basin.*

SMEC. (2007). *Hydrological Study of the TanaHBeles SubHBasins. Draft Inception Report.* Snowy Mountains Engineering Corporation, Australia.

Solomatine, D. (2002). *Data- Driven Modelling, paradiegm, methods, experiences.* UK.

Stedinger, J. R. (1985). *Multisite ARMA(1,1) and Disaggregation Models for Annual Stream flow Generation.* Water Resour. Res.

Thompstone, R. H. (1985). *Forecasting quarter-monthly river flows.* Water Resources Bulletin.

Tong, H. L. (1980). *Treshold autoregression, limit cycles and cyclical data.*

U. Piock-Ellena, R. M. (1999). On the Regionalization of Flood Frequencies- Catchment Similarity Based on Seasonality Measures. Vienna, Austria.

Wale, A. (2008). *Hydrological Balance of Lake Tana Upper Blue Nile Basin, Ethiopia.*

WANG, W. (2006). *Stochasticity, Nonlinearity and Forecasting of Streamflow processes.* China.

Wedgbrow C.S., W. R. (2001). *Prospects for Seasonal Forecasting of Summer Drought and Low River Flow Anomalies* . England and Wales.

Yurkli K., K. A. (2005). *Testing the residuals of an ARIMA Model on Cekerek stream watershed.* Turkey.

Wastewater Management in Wet Coffee Processing Mills and their Impact on the Water Quality Status of Gidabo River and its Tributaries, Southern Ethiopia

Mihret Dananto Ulsido[1], Meng Li[1]*

[1.] *School of Civil Engineering and Architecture, Wuhan University of Technology, Wuhan 430070, China.*

Abstract

Gidabo River and its tributaries are the major sources of water for more than 1.5 million inhabitants. It is an important source of water for surrounding rural communities. The River is the main tributary of Lake Abaya which is the second biggest lake of the rift valley lake basin. The present study was designed to investigate the impact of the wet coffee processing industry on the water quality status of the river and its tributaries. To assess the water quality status, water samples were collected in monthly interval for period of three months from September to November (coffee processing time), 2014. Arc GIS 9.3, 3 DEM and spread sheet were used to analyze the data captured from field observation and SRTM (Shuttle Radar Terrain Model, 90m). From analyzed water quality parameters; turbidity, Biochemical Oxygen Demand (BOD_5), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), pH, Ni, Fe, NO_3^-, and PO_4^{3-} were higher than the recommended national and international standards for aquatic life. A new objective function called WAM-WQI (weighted arithmetic mean (WAM) water quality index (WQI)) were developed, modified and employed in this research. Based on WAM-WQI calculation, the watershed WQI value ranged between 34.83 and 54.31 at different reaches which categorized the river and its tributaries under bad category. Watershed based inventory of wet mills showed that 63.32 liters of processing water was used to produce a kilogram of green coffee bean. Traditional lagoons, having an average hydraulic retention time (HRT) of about 2 days, were used to handle the wastewater. The wet coffee processing industry was discovered as the main sources of contamination in the watershed. The river and its tributaries are under higher risk of deleteri-

Introduction

People living under water-stressed condition in the globe were ranges from 1.4 billion to 2.1 billion (Vorosmarty et al., 2000). The pollution of water bodies by foreign materials inhibits its suitability for intended uses and aggravates the problems of water shortage. One of the major factors that contributed for water pollution has been the rapid pace of industrialization. In Ethiopia, despite the current phenomenal strides in agricultural progress and industrial expansion, inadequate dissemination and restrained access to environment-friendly technologies along with weak enforcement of environmental regulation, have resulted in extravagance of unhealthy industrial practices causing cascading environmental pollution in the receiving watershed. Large scale indifference on part of industries as well as the state has led to massive releases of industrial waste and toxic effluents into nearby river causing immense orders of environmental pollution and health hazards for major forms of life. Often such industrial effluents comprise of products and by-products of toxic and lethal materials, untreated chemicals like Chromium, Nickel and Iron etc. that not only pollute the water and environment but also endanger the health of millions of human inhabitations as well as domestic and wild animals at large (Alemayehu and Rani, 2008).

There are more than 285 Wet coffee processing industries in Gidabo Watershed distributed and concentrated around Gidabo River and its tributaries. Quality coffee has its own method of production. Basically there are two coffee processing methods: dry and wet coffee processing. The way of processing determines the quality of the end product. Each processing technique has a different environmental pollution potential. The most simple and least environment polluting way of processing is the dry method, mostly applied for Robusta coffee (Adams and Dougan, 1987). In this method cherries are picked and left in the sun until the whole fruit reaches a moisture content of around 11%. After drying, the outer flesh and parchment is removed in one step.

In contrast to the dry method, wet processing requires a higher degree of processing know how and is applied mainly for Arabica coffee.

Procedurally it requires mechanical removal of pulp with the help of water as a result of which it produces considerable amount of wastewater. The water used for de-pulping of the coffee cherries is known as pulping water and it accounts for over half of the water used in the process. The wastewater has high concentration of organic pollutants like pectin, proteins and sugars, nitrate, phosphate, if released without treatment; it will be deleterious for the water bodies, human health and the local environment in general (von Enden and Calvert, 2002). The finer quality in Arabica coffee from wet process was due to a pre-sorting step of cherries which only allow ripe cherries in the process. This is done during an approximate fermentation time of 36 hours depending on natural conditions like altitude and temperature (Rothfos, 1979). Only after the mucilage layer has been hydrolyzed, all residues are washed off and the clean parchment is ready for further processing like drying (Vincent, 1987).

Every year from September to January, majority of the wastewater in Gidabo watershed comes from hundreds of wet coffee processing industries. This watershed is considered as a home for quality brooks and the "green gold", Arabica coffee of *Sidama* and *Cheffe* varieties, exported to the international market. Due to lack of intensive research on the water quality status of Gidabo River and tributaries on a regular basis and its impact on the river ecosystems; potentials and risks of the river for different purposes were not well addressed.

Therefore, this study aimed at identifying the impacts of wet coffee processing wet mills on the water quality status of rivers and tributaries in Gidabo watershed. The study evaluates if certain wastewater management strategies of these industries have any impact on the water quality of the river. The hypothesis of this research was *"the effluent from wet coffee processing industries compromised the quality of rivers and tributaries in Gidabo watershed"*. Accordingly, the research questions were organized as: Is there trends in the distribution of wet coffee processing industries in the watershed? What is the water quality status of Gidabo River and tributaries? What is the impact of the wet coffee processing industrial effluents on the quality of the receiving water source? How does a coffee processing industry in the watershed handle its wastewater? The next sections presented the materials used and the methods followed in the study. Section three and four were devoted for results, discussions and conclusions.

Material and Methods

The study area

Gidabo watershed (Figure 1) is the home for more than 1,584,646 inhabitants (CSA, 2005). The absolute geographical location of the watershed is between 6.09^0 and 6.6^0 N latitude and 38^0 and 38.38^0 E longitude with an area and perimeter of 3342.37 square kilometers and 305.25 kilometers respectively. The total length of the watershed is about 76 kilometers with maximum flow distance of about 117 kilometers. The length of the longest river in the watershed is about 38 kilometers and the maximum stream slope is 0.15 percent.

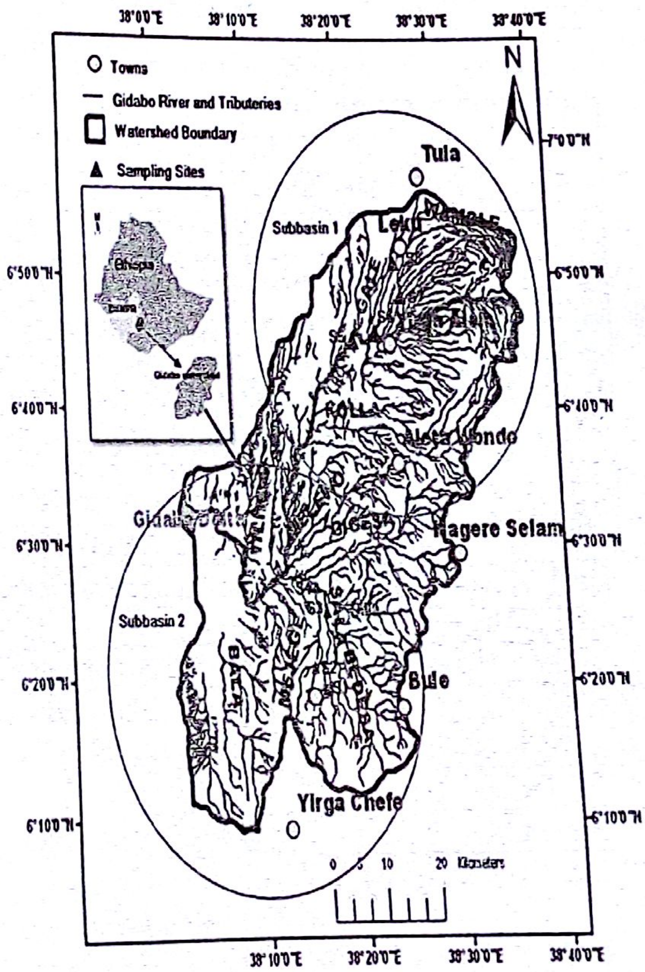


Figure 1. The study area (Gidabo watershed)

Sample Collection and Analysis

The method of sample collection was according to WHO wastewater guideline (WHO, 2006), and American public health association guideline (APHA, 1998). Thus, a total of 15 water quality parameters from 8 sample locations in the watershed were collected to investigate the water quality status of the river and tributaries. Moreover, two additional effluent wastewater samples from wet coffee processing industries downstream of site S1 and S8 were taken to investigate the characteristics of the effluent as compared with the water quality measured at S1 and S8 locations respectively.

Grab sampling was done in monthly interval for three months, September 21,2014 up to November 21, 2014 in eight selected sampling sites at twelve noon, 30cm from surface and 1m above the bottom of the river. All samples were triplicated every round of sampling. Mean values were used here for analysis. The sampling sites were purposely selected based on the relative importance, location and magnitude of wet coffee processing industrial influences. Sample site S1 (upstream of Small Bedessa river), S2(South of Dilla town in Dilla Zuria District), S3 (Chicu river, North of Dilla town), S4(at the creek between Dilla Zuria District of Gedio Zone and Dara District of Sidama Zone), S5(at Kege and Wenenta wet coffee processing mills on Gidabo river bridge near Aposto town), S6 (Gidabo river at old Yirgalem Town of Dale District), S7(Gidabo at Chume village of Dale District), S8(at Telamo creek of Teremessa village in Shebedino district). The Geographical Distributions and coordinates locations were presented in Figure 1 and Table 1 respectively.

Table 1.Sampling Sites locations

No	Location	Sample Numbers							
		Sub Basin 2				Sub Basin 1			
		S1	S2	S3	S4	S5	S6	S7	S8
1	Northing	708019	708214	711115	712485	746571	746572	751625	758343
2	Easting	419521	420734	421590	419192	431182	435553	437534	439213
3	Site	Bedessa	Dilla S.	Dilla N.	Bridge	Aposto	Arada	Chume	Teremesa
4	Woreda	Dila Zuria	Dila Zuria	Dila Zuria	Dilla-Dara	Dale	Dale	Dale	Shebedino

The water quality parameters which are analyzed in this study were illustrated on table 2 below.

Parameters	Methods and Apparatuses
pH, Temperature, EC, TDS	pH and conductivity meter (HANNA pH211)
PO_4^{3-}, NO_3^-	Photometric measurements using flame photometer
COD	dichromate reflux method through oxidation of the sample with potassium dichromate in sulphuric acid solution followed by titration
BOD_5&DO	Winkler-Azide dilution technique
Turbidity	Nephelometeric (HACH, model 2100A)
Mg, Ca, Cr, Ni	Atomic absorption spectrometer, AASP (Varian SP-20) using their respective standard hollow cathode lamps (APHA, 1995).
Iron	UNICAM UV-300 thermo electrode.

Data points mapping

Comprehensive surveys were conducted by providing tabular questioner for 11 districts in the watershed regarding the status of wet mills. Using the tabular sheet variables such as: District name, name of coffee washing plant, its location (village name, Northing (UTM, Universal Transverse Mercator system), Easting (UTM), number of lagoons in each mills, lagoon size (m^3), average daily total water requirement (m^3), weight of fruit pulped per day (Kg/day), management of solid and liquid waste in the industry were identified. Using this data, each wet coffee processing industries were mapped on a GIS interface for decision making. The topographic map was generated from Digital Elevation Model (DEM) derived from a 90m-resolution Shuttle Radar Terrain Model (SRTM). Arc GIS 9.3 software from ESRI was used to prepare all the maps in this document.

Data Aggregation

Separate descriptions of each water quality parameters are time consuming and do not yield appropriate understanding to monitor and control the water bodies. WQI was employed to aggregate individual water quality parameters. It is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers (Puri et al., 2011).

The method numerically summarizes the information from multiple water quality parameters into a single value that can be used to compare data from several sites and months. The use of WQI simplifies the results of analysis related to a water body as it condenses in one value of all parameters analyzed (Warhate&Wankar, 2012). There are a number of indices developed in many parts of the world to evaluate water quality status and pollution extents of the water bodies like U.S NSFWQI (Sharifi, 1990), BCWQI (CME,1995), OWQI (DEQ, 2003), and Smith's Index (Smith, 1987).

For this investigation, WQI, was calculated based on the weighted arithmetic mean (WAM) model where different water quality parameters are multiplied by a weighting factor and then are aggregated using simple arithmetic mean as:

$$WQI = \sum_{i=1}^{n} SI_i \times W_i \qquad \text{Equation (1)}$$

Where SI_i= Sub-index i, n= No of sub-indices, W_i= Weight given to sub-index

Specifically, the normalized objective WQI (equation (2)) modified from WAM-WQI proposed by Conesa and other researchers (Pesce and Wunderlin, 2000; Conesa, 1995 and Sa´nchez et al., 2006) was used for aggregation . It is re-written as:

$$WQI = K\frac{\sum_{i=1}^{n} C_i \times W_i}{\sum_{i=1}^{n} W_i} \qquad \text{Equation (2)}$$

Where: C_i= Normalization Factor (Sub-index i), W_i= Weight given to sub-index, k is a subjective constant which represents the visual impression of river contamination. It can take a value of 1 for water without apparent contamination or 0.75 for a slightly contaminated river or 0.5 for turbid contaminated water. For highly contaminated water characterized by blackish color, hard odor, visible fermentation, a value of 0.25 is assigned. To avoid such type of subjectivity, for this research a value of unity was considered for k. A similar methodology was employed by Nives (1999) and Hernandez-Romero et al., (2004).

C_i is the value assigned to each parameter after normalization (Table 2). W_i is the relative weight assigned to each parameter (Table 3). Wi value range from 1 to 4, with 4 representing a parameter that has the most importance for aquatic life preservation (Total dissolved solid and dissolved oxygen), while a value of 1 means that such parameter has a smaller impact (like pH, trace elements and temperature in a specific watershed. Only those parameters shown in Table 2 and Table 3 were considered for WQI calculation (Conesa, 1995).

Table 3. Parameters considered for WQI calculation adapted from Pesce and Wunderlin (Pesce and Wunderlin, 2000)

WQP*	Weight (Wi)	Normalization Factor (C_i)										
		100	90	80	70	60	50	40	30	20	10	0
BOD-5	3	<0.5	<2	<3	<4	<5	<6	<8	<10	<12	≤15	>15
Ca2+	1	<10	<50	<100	<150	<200	<300	<400	<500	<600	≤1000	>1000
EC	2	<750	<1000	<1250	<1500	<2000	<2500	<3000	<5000	<8000	≤12,000	>12,000
COD	3	<5	<10	<20	<30	<40	<50	<60	<80	<100	≤150	>150
DO	4	≥7.5	>7.0	>6.5	>6.0	>5.0	>4.0	>3.5	>3.0	>2.0	≥1.0	<1.0
Mg2+	1	<10	<25	<50	<75	<100	<150	<200	<250	<300	≤500	<500
NO_3^-	2	<0.5	<2.0	<4.0	<6.0	<8.0	<10.0	<15.0	<20.0	<50.0	≤100.0	>100.0
pH	1	7	7 to 8	7 to 8.5	7 to 9	6.5 to 7	6 to 9.5	5 to 10	4 to 11	3 to 12	2 to 13	1 to 14
PO_4^{3-}	1	<0.16	<1.60	<3.20	<6.40	<9.60	<16.0	<32.0	<64.0	<96.0	≤160.0	>160.0
TDS	2	<100	<500	<750	<1000	<1500	<2000	<3000	<5000	≤10000	≤20,000	>20,000
T	1	21/16	22/15	24/14	26/12	28/10	30/5	32/0	36/-2	40/-4	45/-6	>45/<-6
Turbidity	2	<5	<10	<15	<20	<25	<30	<40	<60	<80	≤100	>100
Fe	1	<0.3	<0.5	<1	<1.5	<2	<3	<4	<5	<6	≤8	>8
Nickel	1	<0.02	<0.025	<0.035	<0.045	<0.055	<0.065	<0.075	<0.085	<0.095	≤0.097	>0.097
Chromium	1	<0.05	<0.055	<0.065	<0.075	<0.085	<0.095	<0.105	<0.115	<0.125	≤0.135	>0.135

**WQP-Water Quality Parameters, W_i- Relative weight, C_i- Normalization Facto*

The resultant WQI values range between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality. When the values of WQI are in the range of 0 to 25, the water is be classified as "very bad"; for a WQI value in the range of 26 to 50 the water is classified as "bad"; for WQI values in the range of 51 to 70 the water classification is "medium"; finally, when the WQI values are within the range of 71 to 90 and 91 to 100 the water is classified as "good" and as "excellent", respectively (Jonnalagadda and Mhere, 2001; Hernandez-Romero et al., 2004).

Results and Discussion

Trends in wet coffee processing mills distribution

Mapping results of 285 wet coffee processing plants in the watershed showed that most of them are concentrated upstream of the main Gidabo River or upstream of major tributaries (Figure 2). The huge volume of clean water required for many processing activities, especially for washing the fermented beans after fermentation tanks, encourage industries to look for relatively clean water. With the perception that clean water found only in upstream creeks, their distribution shows hanging-up at the upstream river trends contaminating the rivers from their sources. Those industries found downstream, either uses groundwater or public water supply system for final processing. These industries were positioned near the river only for the purpose of looking for cheap waste disposal site, the river.

It is observed that all the industries were using water extensively. If the industry's water recirculation system is fully functional they only consume about 22 liter (Adams, 2006) of water to completely wash a kilogram of coffee (Table, 4). However, due to non functional recycling systems, currently they are consuming on average 63.32liters of water to wash a kilogram of coffee (Table 4 and Table 8).

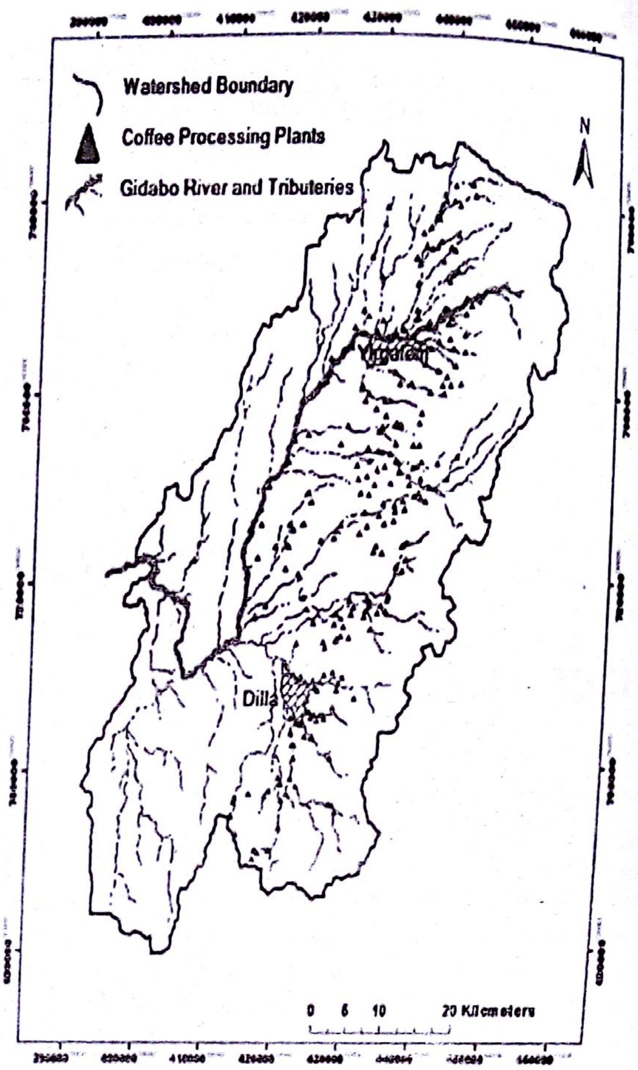


Figure 2. Distribution of wet coffee processing industries in Gidabo Watershed

From the data collected 90% of the industries lack either a water recycling system or was not functional. Accordingly, 68% of the private and 92% of cooperatives owned industries have none functioning water circulation system. The next section presented the water quality status of rivers and tributaries around the coffee processing industries.

Table 4: Experiences on water use in wet coffee processing industries

S.N	Country	water use (l/kg)	Recycling	Remark	Reference
1	Costa Rica	22.52	Yes	Minimum water use	Adams, 2006
2	Costa Rica	90.07	No	Maximum water use	Adams,2006
3	Nicaragua	80.00	Yes	Traditional, fully washed	BIOMAT, 1992
4	Vietnam	22.08	Yes	Robusta Coffee	Mels,2005
5	India	77.50	No	Traditional, fully washed	Deepa,2002
6	Ethiopia	63.32	No	Current Research	Table 8

Water Quality Status of the watershed at Different Reaches

Among the water quality parameters tested turbidity, BOD_5, DO, COD, pH, Ni, Fe, NO_3^-, and PO_4^{3-} were the main constraining parameters which were above or below the recommended limits of WHO for domestic water uses or EPA guidelines or aquatic life.

In the range of temperature between 14°C to 25°C, the expected amount of dissolved oxygen varies between 10 mg L^{-1} to 8 mg L^{-1} but it was observed that in all sites the amount of dissolved oxygen was almost empty (Table 5). This shows that the water is already dead which cannot support any life forms.

Table 5-Physicochemical water quality characteristics of Gidabo River and its tributaries

Para.	Site sample taken								WHO[a]	Local[b]	Natural water[c]
	S1	S2	S3	S4	S5	S6	S7	S8			
EC	103.3	581	404	486.1	752	742.5	749.1	179.1			
TDS	69.3	405.8	280.2	338.3	522	517.4	521.3	117.2	1500	**1000**	
pH	6.3	**4.6**	**5.4**	**4.6**	**5.04**	**5.12**	**5.05**	7.48	1000	3000	176
Temp	**14.1**	18	15.5	18.6	26	25	25.7	24.2	6.5-8.5	6-9	6-9
DO	**0.06**	**0.01**	**0.01**	**0**	**0**	**0**	**0**	**0.04**	15-30	40°C	15
Turb.	**34.6**	**241**	**45.3**	**95.3**	**516**	**447**	**486**	**20.6**	>5	>4	>9
Fe	**1.2**	**13.5**	**1.4**	**17.8**	**7.6**	**2**	**7.3**	7.6	<5	50	<5
BOD_5	**540**	**600**	**402**	**346**	**392**	**254**	**300**	**300**	0.3	10	
COD	**1330**	**3830**	**1102**	**2735**	**3710**	**1618**	**2669**	**2665**	<5	80	<5
Mg^{2+}	4.04	5.62	5.6	5.8	6.2	6.2	3.94	3.96		250	<10
Ca^{2+}	35.36	89.72	31.43	70.97	**160**	**167.3**	39.29	37.5	200	100	
NO_3^-	4.8	**60**	**130**	**100**	**145**	**200**	**48**	**53**	100	150	
PO_4^{3-}	**0.57**	**1.25**	**8.75**	7.5	**22**	**40.5**	**0.15**	**0.08**	45	20	<10
Cr	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.02**	5	10-50*
Ni	**0.04**	**0.08**	0.005	**0.041**	**0.15**	**0.13**	**0.14**	**0.13**	0.05	**0.5**	
									0.02	3	

Note: All units are in mg L^{-1} except Temperature, Turbidity, EC, and pH which are expressed in °C, NTU, $\mu S\ cm^{-1}$, and $[H^+]$ respectively, * $\mu g\ L^{-1}$. [a] World Health Organization standard for Domestic Use, [b] Ethiopia's National Standard for release to natural rivers, [c] Natural unpolluted water quality values . Bold test indicates result above or below WHO limits

pH is very important since it affects the solubility and availability of micronutrients and how they can be utilized by aquatic organisms. The pH of the river and its tributaries ranged in between 4.6 and 7.48 with 4.6 measured at the main Gidabo River and 7.48 for the upstream creek located at Shebedino Woreda. From the eight sampling points, seven of them show lower pH than neutrality. These may reveals the increment of either acidic waste or organic matter load to the river ecosystem from the coffee processing industries as decomposition of organic matter leads to decrease in pH (WHO, 1984). At six observation points, it surpasses the local permissible limits for natural river release, 6-9 (EEPA, 2003) as well as international standards for aquatic life 6.5-9 ,(WHO, 2006). In all observation points the turbidity level is above all existing standards. The consumption of more turbid water may constitute a health risk as excessive turbidity can protect pathogenic microorganisms from the effect of disinfectants like solar radiation, and stimulate the growth of bacteria (Zvikomborero, 2005). Hence the turbidity value of the river water was higher than the prescribed limits <5NTU WHO (1993) and (EEPA, 2003).

BOD is a measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions (Tenagne, 2009). Unpolluted, natural waters should have a maximum BOD_5 and COD value of 5mg L^{-1} and 10 mg L^{-1} or less respectively but on this study the river and its tributaries water BOD_5 and COD values are above all standards. The elevated values of BOD_5 and COD in the river may show the great pollution of the river by different activities in the watershed.

Nitrogen can exist in water in four forms like NH_3, NO_3^-, NO_2^- and NH_4^+ and which may causes groundwater and surface water pollution if it exists in excessive quantity through leaching, stimulates algal growth in surface water that increases maintenance costs in irrigation practices, carcinogenic and blue-baby diseases in infants of human being. The concentration of NO_3^- in the river water was above the permissible limit (WHO, 2006; FAO, 1985) for drinking and irrigation water uses. Nitrite and nitrate should be less than 0.001mg L^{-1} and 0.1mg L^{-1} respectively for favorable aquatic life (Murdoch et al., 2001) but the river and most of its tributaries had high nutrient contents which depart more from natural desirable levels.

Nitrate is the most soluble and highly susceptible for leaching thus it can cause even ground water pollution. Its main source is decomposition of organic matter like coffee waste, fecal matter and municipality waste.

The concentration of phosphate in the river and its tributaries was higher than the recommended limits to freshwater healthy ecosystem (EEPA, 2003), due to this the river is categorized in eutrophic state index (Carlson, 1977). However, according to Chapman (1996) the nutrients level in river water shows great impairment of the river ecosystem by point and non-point sources of pollution.

Trace levels of dissolved metals in surface water are essential for proper biological functioning in both plants and animals (CCME, 2009). The concentration of metals in the river was high due to point sources of pollution from those industries discharging their waste directly to this river. However, except Nickel and Iron, other metals are within the permissible allowable limits to all designated water uses (CCME, 2009; EU, 1998; WHO, 1998). To investigate the pollution distribution trends in the watershed, individual water quality parameters were weighed and the aggregated results were presented in the next section.

Aggregated Water Quality Values

A WQI analysis is separately done to aggregate the individual water quality parameters at different reaches of the watershed (Table 6).

Table 6. WQI of Gidabo River at Different Reaches

i	Parameter	Wi	Sample Numbers															
			Sub basin 2								Sub basin 1							
			S1		S2		S3		S4		S5		S6		S7		S8	
			Ci	CiWi	Ci	CiWi	Ci	CiWi	Ci	CiWi	Ci	CiWi	Ci	CiWi	Ci	CiWi	Ci	CiWi
1	T	1	80	80	10	100	90	90	10	100	70	70	75	75	70	70	80	80
2	pH	1	55	55	35	35	45	45	35	35	40	40	43	43	40	40	90	90
3	DO	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	TDS	4	10	400	90	360	90	360	90	360	80	320	80	320	80	320	90	360
5	EC	3	10	300	10	300	10	300	10	300	90	270	10	300	10	300	10	300
6	Turbidity	2	40	80	0	0	30	60	10	20	0	0	0	0	0	0	60	120
7	NO_3^-	2	70	140	10	20	0	0	10	20	0	0	0	0	20	40	10	20
8	PO_4^{3-}	1	90	90	90	90	60	60	60	60	40	40	30	30	10	100	10	100
9	COD	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	BOD5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Ni	1	70	70	30	30	10	100	70	70	0	0	0	0	0	0	0	0
12	Cr	1	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100
13	Ca	1	90	90	80	80	90	90	80	80	60	60	60	60	90	90	90	90
14	Mg	1	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100
15	Fe	1	70	70	0	0	70	70	0	0	10	10	60	60	10	10	10	10
	∑Wi & ∑CiWi	29		1575		1215		1375		1245		1010		1088		1170		1370
	WQI= ∑CiWi/∑Wi		54.31		41.90		47.41		42.93		34.83		37.52		40.34		47.24	
	WQI_{mean}		46.63								39.98							
	Pollution state		Medium		Bad		Bad		Bad		Bad		Bad		Bad		Bad	

Based on the above separate WQI computation for aquatic life support system, the mean WQI value of 39.98 observed at sub basin 1 indicated that the main Gidabo river is already polluted at the upstream source. This analysis is coinciding with the high population of wet coffee processing industries at the same reach (Figure 2). Except at sampling site 8, all sampling points showed that the water quality of the river and its tributaries between September and November are bad for domestic and aquatic life. So, mitigation measures should have to be developed in the watershed overall activities, particularly remediating the solid waste and liquid wastewater releases from wet coffee processing industries. To explore the direct contributions of the coffee processing industries on the water quality, wastewater effluent characteristics of the industries were analyzed and presented in the next section.

Impacts of the wet coffee processing industries

In depth observation of the impacts of wet mills and their contribution on the quality of the receiving water sources were conducted by taking additional samples from effluents from two industries located at sub basin 1 and sub basin 2 which takes S1 and S8 as their influent water sources. The data showed that the effluent water quality were significantly pollutes by organic and inorganic pollutants as compared with the influent water (Table 7).

Even though it is within the threshold level, the concentration of calcium and magnesium rose from influent to effluent level. Trace elements (nickel and iron) measurement showed a raise in concentration from influent to effluent. On the other hand, chromium was not detected both in the influent and effluent samples. Effluent turbidity (Table 7, Figure 3) and COD were the two parameters that showed a higher percentage of increment as compared with the influent concentrations at sub-basin 1. The change is due to the contribution of the pulping operation of the processing industries. Thus, the data depicted that coffee liquid waste cause serious natural water turbidity and were sources of organic matter loading that impaired the rivers water quality in Gidabo watershed. pH values also showed a shift from neutrality to acidity indicating that wet coffee processing industries are also a source of acidic effluent in the basin.

Table 7. Mean physicochemical analyses of Influent and Effluent Waste

No	Parameters	Sample site					
		Sub basin 2 at S1			Sub basin 1 at S8		
		Influent	effluent	Change (%)	Influent	effluent	Change (%)
1	EC	103.3	486.1	370.6	179.1	749.1	318.3
2	TDS	69.3	338.3	388.2	117.2	521.3	344.8
3	pH	6.3	4.6	-27.0	7.48	5.05	-32.5
4	Temperature	14.1	18.6	31.9	24.2	25.7	6.2
5	DO(mg/l)	0.06	0.00	-100.0	0.04	0.00	-100.0
6	Turbidity(NTU)	34.6	95.3	175.4	20.6	486	2259.2
7	Iron(Fe), (mg/l)	1.2	17.8	1383.3	7.6	7.3	-3.9
8	BOD5(mg/l)	54	346	540.7	30	300	900.0
9	COD(mg/l)	133	2735	1956.4	64.5	2669	4038.0
10	Magnesium	4.04	5.8	43.6	3.96	3.94	-0.5
11	Calcium	35.36	70.97	100.7	37.50	39.29	4.8
12	NO_3^-	4.8	100	1983.3	48	48	0.0
13	PO_4^{3-}	0.57	7.5	1215.8	0.08	0.15	87.5
14	Chromium	<0.0001	<0.0001	0.0	<0.0001	<0.0001	0.0
15	Nickel	0.037	0.041	10.8	0.13	0.14	7.7

All units are in mg L^{-1} except Temperature, Turbidity, EC, and pH which are expressed in °C, NTU, uS cm^{-1}, and [H^+] respectively

Figure 3. Turbidity of the receiving stream after the effluent released at Beshura wet mill site, Shebedino Woreda

Effluent iron, NO_3^-, PO_4^{3-} and COD were the parameters that showed a higher percentage of increment as compared with the influent concentrations at sub-basin 2. The elevated iron concentration was partly associated with the corroding distribution system and old processing parts in the industrial complex. NO_3^-, PO_4^{3-} and COD were directly evolved from the wet coffee processing residues (von Enden and Calvert, 2002).

However, each wet coffee processing industries have at least one wastewater collection lagoons. Therefore, how cans wastewater reached the river? To investigate this scenario, wastewater management behavior of the industries were analyzed and presented in the next section.

Handling of wastewater by wet coffee processing industry

To contain the wastewater from the processing industries, aerobic lagoon based systems are usually practice in the watershed. Lagoons play a momentous role in treatment of municipal sewage and intensive agro processing industry wastewater. They provide reasonable and effective treatment if properly managed. Waste water characteristics, the amount of wastewater loaded, the type of pond used (aerobic, anaerobic, facultative, aerated, maturation), arrangement of lagoons and weather conditions are major factors that affect the performance of lagoon based system treatment. The coffee washing plants have neither adequate number of lagoons nor have sufficient capacity to accommodate waste water for extended retention time. Most of the plants incorporate two lagoons with average depth of 1.5m. Nearly all Lagoons are not lined, not systematically arranged or interconnected in such a way that waste water can be transferred from one to another in order to allow better oxidation for the minimization of BOD load within sufficient retention time.

One of the important factors that influence reduction of organic pollutants of wastewater in lagoons is the duration allowed to complete the oxidation process. It requires as long time as possible to achieve permissible effluent BOD level. Determination of residence time depends on some factors such as BOD load, pond depth and temperature. Almost all coffee washing lagoons cannot accommodate the waste water for more than three days (Table 8). The average hydraulic retention time of 1.99 days (Table 8) was not enough to degrade the pollutants in the wastewater.

Table 8. Residence time (HRT) of wastewater at different districts of the Gidabo Watershed

S/N	Districts observed	Number of Lagoons	Total Lagoon size (m3)	Total Daily water discharge (m3.day-1)	Dried bean equivalent per day (kg/day)	Unit Water Requirement (l/kg)	HRT (days)
1	Bule	6	860.00	450.00	7740	58.14	1.91
2	Dale	119	22779.00	8700.00	167760	51.86	2.62
3	Dara	63	11721.00	4945.00	61920	79.86	2.37
4	Wensho	32	11635.00	2720.00	68800	39.53	4.28
5	Shebedino	48	11728.50	7280.50	107280	54.39	1.61
6	Loka Abaya	13	1860.00	1680.00	19320	86.96	1.11
7	Dilla Zuria	60	8771.99	5220.00	72000	72.50	1.68
8	Wenago	34	8160.00	5040.00	No data	No data	1.62
9	Yirga Cheffe	2	650.00	250.00	No data	No data	2.60
10	Aleta Wendo	97	10494.00	9900.00	No data	No data	1.06
11	Chuko	57	6037.76	5696.00	No data	No data	1.06
	Total	531	94697.25	51881.50			
	Average		8608.84	4716.50		63.32	1.99

This clearly indicates that the wet coffee processing industries were surface or subsurface releasing non degraded wastewater to the nearby water sources. Hence, the observed water quality impairment from September to November 2014 in Gidabo Watershed was mainly caused by wet coffee processing industries in the watershed.

Conclusions and Recommendation

The current study evaluated the physicochemical water quality characteristics of Gidabo River and its tributaries. Water quality parameters analyzed and examined from various sampling sites in the watershed. It was observed that the river water is unsuitable for domestic use and aquatic life for that particular coffee processing season. Even though, both point and non-point sources of pollution beside the natural factors weaken the quality, the river quality is mainly influenced by effluents from wet coffee processing industries which are located at the source of the river and its tributaries. From fifteen randomly selected water quality parameters, Gidabo river and its tributaries failed to fulfill the national and international standards on turbidity, BOD_5, DO, COD, pH, Ni, Fe, NO_3^-, and PO_4^{3-}. The WQI analysis showed that the river and its tributaries were categorized as "bad" for aquatic life and domestic uses during the coffee processing seasons (from September to late January). The traditional processing practice which uses about 63.32 liters of water to process a kilogram of dried beans; and poorly designed/ standardized wastewater detention basins which have a HRT of about 2 days were the precursors of the problem. Hence monitoring the effluent standards of the surrounding industries; mainly the wet coffee processing industries are extremely essential to protect the river water quality from further deterioration. For further investigation, the monthly evaluation of physicochemical water quality characteristics for two years; twice in the coffee production season from September to January and twice in the off seasons from February to June is ongoing to get a coherent overview of the quality impairment scenarios and rivers regeneration capacity in the watershed.

Acknowledgements

This work is supported by Wuhan University of Technology through Chinese Government Scholarship and Czech University of Life Sciences. The authors would like to thank Hawassa University, Institute of Technology, School of Biosystems and Environmental Engineering: MSc Students of Water Resources Engineering in the weekend and summer programs of the year 2014 and Water Supply and Environmental Engineering 3rd year students for their support during data collection. Mr. Tigistu from the School of Biosystems and Environmental Engineering deserves recognition for his collaboration in water quality analyses.

References

Adams, M.R. and J. Dougan. 1987. Green Coffee Processing. In: Clarke, R.J. and R. Macrae, ed., Coffee. Volume 2: Technology. New York, NY: Elsevier Science Publishers, pp. 257 – 291

Adams, M.A. A ,2006. Multi□Criteria Evaluation Methodology for an Economically and Environmentally Sustainable Coffee Industry. Dalhouise University. Halifax, Nova Scotia, Canada. March

Alemayehu Haddis, Rani Devi. 2008. Effect of effluent generated from coffee processing plant on the water bodies and human health in its vicinity. Journal of Hazardous Materials 152: 259-262.

APHA (American Public Health Association). 1995. Standard methods for the examination of water and waste water. 18th Edn. APHA; Washington DC, USA.

APHA, AWWA and WPCF. 1998. Standard Methods for the Examination of Water and Waste-water 18th ed . Washington, U.S.A., pp. 2-27, 4-108,4-117, 4-131, 10-26.

BIOMAT. 1992. Matagalpa, Nicaragua: Alcaldía de Matagalpa and Oficina Biogás y Saneamiento Ambiental.

CCME (Canadian Council of Ministers of the Environment). 2009. Guidelines for Canadian recreational water quality. Prepared by the Federal-Provincial-Territorial Working Group on Recreational Water Quality of the Federal-Provincial-Territorial Committee on Health and the Environment.

Chapman, D., (ed.). 1996. "Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water." Environmental Monitoring. Second Edition. UNESCO, WHO, and UNEP. E&FN Spon, London UK.

Conesa Fdez-Vitora.1995. Methodological Guide for Environmental Impact Evaluation (2nd ed.), Mundi-Prensa, Madrid. p. 390

Deepa, G.B.; Chanakya, H.N.; de Alwis, A.A.P.; Manjunath, G.R.; Devi, V. 2002. Proceedings "Symposium on Conservation, Restoration and Management of Aquatic Ecosystems. Canada: Centre for Ecological Sciences, Indian Institute of Science (IIS) and the Karnataka Environment Research Foundation [KERF], Bangalore and Commonwealth of Learning. paper 4.

EEPA (Ethiopian Environmental protection Authority). 2003. Guideline Ambient Environment Standards for Ethiopia. Prepared by EPA and UNIDO under ESDI project US/ETH/99/068/Ethiopia. Addis Ababa.

FAO. 1985. Water quality for agriculture, by R.S. Ayers & D.W. Westcot. Irrigation and Drainage Paper No. 29 (Rev. 1). Rome.

Hernandez-Romero, A. Hector; Cristian Tovilla-Hernandez, Edi A. Malo, Ricardo Bello-Mendoza. 2004. Water quality and presence of pesticides in a tropical coastal wetland in Southern Mexico. Marine Pollution Bulletin, 48 , pp. 1130–1141

Jonnalagadda S. B. and Mhere G. 2001. Water Quality of the Odzi River in the Eastern Highlands of Zimbabwe, Water Research Journal, 35(10), pp. 2371–2376

Mels, A. Martijn, E□J. Kampf, R. and Claassen, T. 2005. Water harmonic in the Developing World. STOWA report 21. STOWA. Utrecht, The Netherlands.

Murdoch, T., Cheo M., and OLaughlin K. 2001. Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods.

Pesce Silvia F. and Daniel A. Wunderlin. 2000. Use of water quality indices to verify the impact of Córdoba City (Argentina) on Suquía River, Water Research 34(11), pp. 2915–2926.

Nives, S.-G. 1999. Water quality evaluation by index in Dalmatia. Water Research, 33 (6), pp. 3423–3440

Puri P.J., Yenkie M.K.N., Songal S.P., Gandhore N.V., Sarote G.B and Dhanorkar D.B. 2011. Surface water (rivers) quality assessment in Nagpur City (India) based on water quality index (WQI). RASAYAN J.Chem. Vol.4, No.(2011),43-48.

Rothfos, B. 1979. Kaffee. Die Produktion. Hamburg.

Sharifi M. 1990. "Assessment of Surface Water Quality by an Index System in Anzali Basin". In The Hydrological Basis for Water Resources Management. IAHS Vol.197, pp163-171.

Smith D. G.1987. "Water Quality Indexes for Use in New Zealand's Rivers and Streams", Water Quality Centre Publication No. 12, Water Quality Centre, Ministry of Works and Development, Hamilton, New Zealand.

Vincent, J.C. 1987. Green Coffee Processing.. In: Clarke, R.J. and R. Macrae, ed., Coffee. Volume 2: Technology. New York, NY: Elsevier Science Publishers, pp. 19 - 32.

Von Enden, J. C. and Calvert, K. C. 2002. Review of coffee waste water characteristics and approaches to treatment.

Vorosmarty, C. J., Green, P., Salisbury, J. and Lammers, R. B. 2000. Global water resources:vulnerability from climate change and population growth, Science, 289: 284-288.

Warhate S.R. and Wankar K.G. 2012. The evaluation of water quality index around Welkorela-Pimperi coal mines. Sci. Rev. Chem. Commu., 2(3),197-200.

WHO . 1993. Guidelines for Drinking Water Quality. 1sted. Geneva.

WHO. 1984. Guidelines for Drinking-Water Quality,Vol 2 health Criteria and Other Supporting Information. Geneva: WHO.

WHO. 1998. Health Guidelines for the Use of Waste water in Agriculture and Aquaculture. Report of a WHO Scientific Group. Geneva, Switzerland: World Health Organization Press.

WHO. 2006. Guidelines for safe recreational Water environments,Volume 2 Swimming pools and Similar environments. Geneva.

Zvikomborero, H. 2005. An assessment of the water quality of drinking water in rural districts in Zimbabwe. The case of Gokwe south, Nkayi, Lupane and Mweezi districts. Phsics and Chemistry of the Earth 30:859-866.

The Role of the Grand Ethiopian Renaissance Dam (GERD) Beyond Generating Hydroelectric Power: Appraising Its Potential Contributions for the Development Water Based Tourism in Ethiopia

Mohammed Jemal Ahmed, MA in Tourism and Development

Lecturer at Jigjiga University, Department of History and Heritage Management

Email: mojem12@gmail.com Mobile Phone: +251913209706

Abstract

The Role of the Grand Ethiopian Renaissance Dam (GERD) Beyond Generating Hydroelectric Power: Appraising Its Potential Contributions for the Development Water Based Tourism in EthiopiaTraditionally, the roles of large dams have been limited mainly to the provision of hydroelectric power generation and irrigation. Likewise, the primary objective of GERD is to generate electric power. However, the benefits of GERD should not be limited only to power supply, it will have another socioeconomic significance through creating tourism opportunities. Tourism is one the most lucrative business that can be seen as a major indirect benefits of hydroelectric power dams. The GERD would fill the gaps of coastal attraction that Ethiopia is naturally lacking and it would enhance the development of lake based tourism. Being a land locked country, there was little water based tourism in Ethiopia. The existing limited water based tourism practice has been confined around Bahr Dar and Hawassa Cities. Hence, the GERD is a God sent opportunity to develop water based tourism in Ethiopia in general and in Benshangul Gumuz in particular. Moreover, the area has a comparative advantage for the development water based tourism. According to Dokulil, a lake that is suitable for tourism must: be easily accessible, have the necessary infrastructure, have warm water surface temperature preferably >20 °C and have good water quality ('clean water'). GERD fulfills almost all of these preconditions. Therefore, the construction of 'Africa's Great Dam' in our country is a great blessings for the development of water tourism.

This dam would contribute for the country's tourism development in various ways: in the first place, the dam itself would become the main tourists' attraction of the country especially for its western part. In another way, this dam will became the largest artificial lake in Ethiopia. So, it may offer various water based tourist activities like boating, fishing, rafting, swimming and other shoreline activities. The dam has also indirect roles for the development of tourism industry in the country via the development of infrastructures in the area and through image building and promotion of the country to the rest of the world. In such a ways, the construction of the Grand Ethiopian Renaissance Dam will open another new chapter for the development of water based tourism in Ethiopia. Hence, it should be accredited that beyond generating electric power, the dam will have multipurpose and a various roles for the country's socioeconomic development.

To this end, the main objective of this paper is to appraise the potential roles of the Grand Ethiopian Renaissance Dam for the development of water based tourism in Ethiopia. For this research, qualitative research has been deployed. The data has been collected through field observations document reviews and interviews.

Key Words: Grand Ethiopian Renaissance Dam, Water Based Tourism and Hydroelectric power

Background

In the 21st century, tourism in general, water based tourism in particular emerges as the fastest growing industry and a significant income generating sector. It has become a key tool to lift people out of poverty and create new opportunities. It has been also serving as an important alternative economic sector for most developing countries. As of 2011, promising project having vital potential for the country's water based tourism development was launched. This promising project and the prospect tourist attraction at the very west part of Ethiopia is the Grand Ethiopian Renaissance Dam (GERD). Having untapped tourism potentials, Ethiopia has been giving special attention for tourism industry and it already launched a new tourism development policy in 2010. Recently, tourism has been contributing for the country's GDP and creating job opportunities for many individuals directly and indirectly.

The Grand Ethiopian Renaissance Dam (GERD) Location and General Description

The Grand Ethiopian Renaissance Dam (hereafter called GERD) was launched on April 2, 2011 at Guba in Benshangul-Gumuz Regional state. The GERD is located approximately 750 km northwest of Addis Ababa on the Blue Nile River at Metekel Zone in Guba Woreda and about 45 Km west of Sudan.

Figure 1: Riparian states of Nile and location of

The National Panel of Experts (NPoE), the dam will have a length of 1780 meters and height of 145 meters and it will be a Roller Compacted Concrete (RCC) gravity dam, divided in three sections: right bank, central section and left bank. With a total generating capacity of 6000MW, the dam has been constructed over the river of Abbay (Blue Nile) which is the trans-boundary river having length of 6700km. Nile is the common resource of eleven African countries: Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, and Uganda.

Generating 6,000 MW, the dam will become the largest hydroelectric power plant in Africa, as well as the 11th largest in the world. The total storage volume of 74 billion cubic meters will be one of the continents' largest.

Statement of the Problem

Since immemorial time the role large dams, was limited on the provision of irrigation, water supply, flood control, and hydropower generation. Even in the the 21st century, it can be shown that the role of Hydropower dam for the development of water based tourism has been given less attention and still closely linked mainly with the development of hydroelectric power infrastructures. Likewise, the primary objective of GERD is to generate an electric power of 6000MW, with an annual energy production of 15130 GWH per year to cover the power supply demand in the country as well as in the East Africa region. However, the benefits of GERD should not be limited only to power supply, this great dam will have another socioeconomic significance. Water Based Tourism is one the most lucrative business that can be seen as a major indirect benefits of hydroelectric power dams. The experience of many countries such as Aswan Dam of Egypt, the Maguga Dam of Southern Africa, the Three Gorges Dam Project at Yangtze River of China and Pyrenees of Spain reveal that hydroelectric power dams have a great contribution for the development of water based tourism industry. Similarly, GERD would play a great role for the development of water based tourism in Ethiopia in general and for western part of Ethiopia and Benishanul Gumuz in particular.

Moreover, researches made by organizations like the Stanford Research Institute and Angus Reid consistently find that between 10% and 15% of discretionary travelers want to visit manmade water bodies such as dam, artificial lakes and waterfalls. The most important thing here is that these tourists are typically highly educated, matured, environmentally aware and sensitive to the host communities' social and cultural traditions and systems. However, most of the time less attention has been given for development of water based tourism business at hydropower dams and as to my knowledge, organized and methodologically sound studies to identify the potential role of GERD for the development of water based tourism in Ethiopia have not been conducted so far.

Objective

The main objective of this paper is to appraise the potential roles of the Grand Ethiopian Renaissance Dam for the development of water based tourism in Ethiopia in general and Benishangul Gumuz Region in particular.

Methodology

This research work has been mainly relied on secondary sources. Secondary data can be a valuable source of information for gaining knowledge and insight into a broad range of issues and phenomena. Review and analysis of secondary data can provide a cost-effective way of addressing issues, conducting cross-national comparisons, understanding country-specific and local conditions, determining the direction and magnitude of change -- trends, and describing the current situation. Accordingly, the researcher has collected data from various documents. Publications which have been written about the GERD, Ethiopian Tourism development, and experiences of other countries in relation with the role of hydroelectric dam for tourism deployment and other related documents have been well targeted and reviewed. An unstructured interview has been made with stakeholders mainly with tourists, scholars and tour operators. Moreover, the researcher made field observation to the study area from April 25-27/2015.

Results and Discussions

Simply for the sake of Convenience, the role GERD for the development of water based tourism of Ethiopia has been classified in to four subtopics. These are the role of the GERD as a tourist attraction by itself, the role of the GERD through image building and tourism Promotion, the role of the GERD as incentives for the development of other attractions of the region and the country and the role GERD in fulfilling the electric power demand of tourists and investors.

The Role of the GERD as a Tourist Attraction

The term water based tourism has been coined by authors s Hall and Harkonnen (2006) being represented by the lakes' potential, both natural and artificial. The lake areas, associated to some relaxing and leisure milieus, with an ecological aura above them have attracted tourists since ancient times, ever since antiquity to the contemporary period.

The informal interview made with stakeholders (scholars, tour operators and tourists) approved that the GERD have a great potential tourists and it would become one of the most veritable attraction of the country perhaps, the first attraction that would draw the attention of both domestic and international tourists in the near future. It is expected that it would fill the existing two major gaps as far as the Ethiopia's tourism development is concerned. In the first place, it would balance the discrepancy of tourist attractions in the country. So far northern historic circuit and a southern ethnological and nature based circuit have been taking the lion's share of the market claiming 95% of tourist arrivals of the Country. Whereas the proper western part of Ethiopia has been sharing less than 1% of the total Ethiopian tourist arrival and its revenue receipts is too little. According to interview made with tour operators, absence of famous tourist attraction in the proper west Ethiopia was the main reason for the underdevelopment of tourism in the area. There were no famous attractions in the proper western part of the Country. Hence, the GERD would become prime tourist attraction in the proper western part of Ethiopia and this dam would fill the gap in this regard.

Secondly, the GERD also expected to compensate the absence of coastal attraction which Ethiopia is naturally lacking and it would enhance the development of lake based tourism. Being a land locked country, there was little water based tourism in Ethiopia. The existing limited water based tourism practice has been restricted around Bahr Dar and Hawassa Cities. Hence, the GERD is a God sent opportunity to develop water based tourism in Ethiopia in general and in Benshangul Gumuz in particular. The area has a comparative advantage for the development water based tourism. According to Dokulil, a lake that is suitable for tourism must: be easily accessible, have the necessary infrastructure, have warm water surface temperature preferably >20 °C and have good water quality ('clean water'). GERD can fulfill almost all of these preconditions.

Moreover, tourist would enjoy with various water based activities such as swimming angling, boating, water sport, Scuba diving, surfing, shoreline activities like bird watching and so on. Fishing and Consumption of fish products would become another niche as far as tourism development of the area is concerned. Having the water volume of greater than our great Lake of Tana and lying 247\ Eastwards from its base, GERD has a great potential in terms of fishing and fish products.

The Role of the GERD as Incentives for the Development of other Attractions of the Region and the Country

In addition to attracting tourists directly, the GERD has also invisible and indirect role for the development of tourism sector in the country and in Benishangul Gumuz Regional state too. The dam would pave the way for the development of other tourism assets of the country and the region too and it would solve the problems that region has been facing in this regard. Tourists' infrastructures which have been built following the emergence of GERD would serve to access other tourists' attractions of the region and the country's as well.

The Role of the GERD for Image Building and Tourism Promotion

Another important contribution of GERD in terms Ethiopia's tourism development is in the area of image building and tourism Promotion.

In the 1980s, the images of Ethiopia as famine and starvation were spread and amplified to TV screens in every corner of the globe. It touched the viewers' hearts, and stayed in people's minds. Since then, a name called Ethiopia become associated with poverty, malnutrition, drought, famine and war. Ethiopia's predominant image in international media remains one of starvation, conflict and barren landscapes and many people in the West continue to see Ethiopia as a charity-case. However, recently, the image of Ethiopia has been changing. Beside to other socioeconomic developments, the construction of GERD took a lion share in changing the former negative image of Ethiopia. Since its inauguration till now, international media such as BBC, Algezira, CCN, Press TV and others have been broadcasting news about the construction of GERD and Ethiopia. For instance, Algezira has prepared a documentary film entitled the "the Struggle over the Nile" and "the Children of Nile" which was a great opportunity to introduce the country for the rest of the world in depth.

It is a paradox that even the Egyptian printing and broadcasting medias have been spreading information about GERD, in contrary of their mission, they have been promoting and introducing Ethiopia in general and the GERD in particular to the rest of the world. In such a way that the GERD open a new chapter as far the Ethiopian image is concerned. Therefore, it is logical to conclude that the GERD played invaluable role in changing the negative image of Ethiopia and in promoting the country's tourism asset to the potential tourists. Therefore, the Construction of GERD would play great role for the development of tourism industry of the country through image building and promotion.

Conclusion and Recommendations

Conclusion

This article has provided an overview of the contribution of Grand Ethiopian Renaissance Dam (GERD) for the development of the country's tourism industry. In the introduction part, the General situation of Benshangul Gumuz Region (a region where GERD being building) have been described. In addition, general facts about GERD have been also discussed.

The contributions of GERD for the country's water based tourism development have been seen from different angles and summarized through the following subtopics: the role of the GERD as a tourist attraction by itself; the role of the GERD through image building and tourism Promotion and the role of the GERD as incentives for the development of other attractions of the region and the country

The informal interview made with stakeholders (scholars, tour operators and tourists) approved that the GERD would become the most veritable attraction of the country, perhaps the first attraction that would draw the attention of both domestic and international tourists in the near future. It is approved that it would fill the existing two major gaps as far as the Ethiopia tourism development is concerned. In the first place, it would balance the discrepancy of tourist attractions in the country. So far northern historic circuit and a southern ethnological and nature based circuit have been taking the lion's share of the market claiming 95% of tourist arrivals of the Country. Whereas the western part of Ethiopia has been sharing less than 1% of the total Ethiopian tourist arrival and its revenue receipts is too little. Absence of famous tourist attraction in western Ethiopia was the main reason for the underdevelopment of tourism in the area. Hence, Ethiopia's Grand Renaissance Dam would solve this problem. Secondly, the GERD also expected to compensate the absence of coastal attraction that Ethiopia is naturally lacking and it would enhance the development of lake based tourism. In addition to attracting tourists directly, the GERD has invisible and indirect role for the development of tourism sector in the country and in Benishangul Gumuz Regional state too. Hence, the dam would pave the way for the development of other tourism assets of the country and the region. Another important contribution of GERD in terms Ethiopia's tourism development is in the area of image building and tourism Promotion. Following inception of the construction of GERD, the image of Ethiopia has been gradually improving and a number of tourists would flow towards Ethiopia. Still the GERD has another contribution in providing sufficient electric power for tourists. When it became completed, GERD expected to generate 6000MW and it would satisfy the tourists' electric power demand.

Generally, the GERD has both direct and indirect role for the development of water based tourism in Ethiopia in general and in Benishangul Gumuz Regional State in particular.

Recommendations

So as to realize the potential of GERD for the country's tourism development and maintain sustainability, the researcher has forwarded the following recommendations.

Like that of Historic Route in the North, Western Route which would run from Addis Ababa to GERD as far Sudan Khartoum should be established. In such a way there should be a free tourist flow from Sudan to Ethiopia and vice versa

Important tourism infrastructure such as Lodges, Standard Hotels, internet and water based services like motorboat and others should be established

The security issue of the area should get a serious attention. A terrorists may targeted the dam. Hence, all stakeholders should play their own role to maintain security and safety of the area. In the long run, tourism police should be deployed at GERD.

A care should be protecting the dam from any kind of pollutions

Host Community Involvement: Major achievement in tourism industry can be achieved by the help of residents of the destination. Local residents can play their role through hospitality, their own small businesses, giving rooms of their homes in areas where hotels are not present, guiding tourists where tourist's guides are not available, arranging local festivals by not increasing the price to items unnecessarily. Therefore, a special attention should be paid in empowering and involving the host community in tourism business.

Bibliography

Alhassan, H.S. 2009. Viewpoint □ Butterflies vs. hydropower: Reflections on large dams in

contemporary Africa. Water Alternatives 2(1): 148□160

Ascehnek Daneil (2013). Grand Ethiopian Renaissance Dam and Sustainable Development

in the Perspective Of Environmental Laws And Standards: Challenges And Prospects. BahrDar University

Ayalew Sisay (2009). *Historical Development of Travel and Tourism in Ethiopia*. Addis Ababa.

Belachew Chekene Tesfa (2013). Benefit of Grand Ethiopian Renaissance Dam Project

(GERDP) for Sudan and Egypt. University of Huddersfield, UK

Cnossen (1997). What is Secondary Data Review and Analysis?

Dale Whittington, John Waterbury and Marc Jeuland (2014). The Grand Renaissance

Dam and prospects for cooperation on the Eastern Nile

De Stefano, Lucia (2004). Freshwater and Tourism in the Mediterranean. Rome, Italy.

www.panda.org/mediterranean

Eric Huskyes, Royal Haskoning and Kevin O'Connor, Donegal County Council, in collaboration

with the Marine Institute (2006). Water-Based Tourism and Leisure. Marine Institute Rinville Oranmore Co. Galway Ireland

Geografie, Seria (2011). Befitting and Disruptive Practices of Water-Based Tourism in the

Crisuri Mountains. University of Oradea, Department of Geography, Tourism and

Territorial Planning, 1 UniversităŃii st.,410087, Oradea, Romania

International Panel of Expert (IPoE) (2013). (International Panel of Expert Report on Grand

Ethiopian renaissance Dam. Addis Ababa

Kalitsi (2013). Problems and Prospects for Hydropower Development in Africa. Novotel, Dakar, Senegal

Kenneth M. Strzepek, Gary W. Yohe, Richard S.J. Tol and Mark Rosegran (2006). The Value of

The High Aswan Dam To The Egyptian Economy. Egypt, High Aswan Dam, computable general equilibrium model, risk premium, water supply

Michael Hammond (2013). The Grand Ethiopian Renaissance Dam and the Blue Nile:

Implications for trans-boundary water governance. UK

Natalie Koziol (...). An Introduction to Secondary Data Analysis

Peter H. Gleick (2009).Three Gorges Dam Project, Yangtze River, China

Rajanda Nigam (2008). Development of Tourism infrastructure on Lakes: its necessity Scope, limitation and pollution and the need for Inland Maritine legislation. Proceeding of World lake Conference: 1200-1201

Rita Cestti and R. P. S. Malik (2008). Indirect Economic

Impacts of Dams. Case Studies from

India, Egypt and Brazil, Academic Foundation, New Delhi and World Bank.

Skinner, J., Niasse, M. and Haas, L. (eds.) 2009. Sharing the benefits of large dams in West

Africa. Natural Resource Issues No. 19. International Institute for Environment and Development, London, UK.

Tamang and Tshering (...). Hydropower - Key to sustainable, socio-economic development of

Bhutan. Ministry of Trade & Industry, Thimphu Bhutan

Tullos, D.; Brown, P.H.; Kibler, K.; Magee, D.; Tilt, B. and Wolf, A.T. (2010). Perspectives on the salience andmagnitude of dam impacts for hydro development scenarios in China.

Water Alternatives 3(2): 71-90 Wilson, Scott (2009). Determination of Waters of National Tourism Significance and Associated

Water Quality Status, Irelan

World Tourism Organization (UNWTO) and the European Travel Commission (ETC) (2011).

Handbook on Tourism Product Development. Madrid, Spain

ANALYSIS OF HYDROCLIMATIC TRENDS IN GUDER SUB-BASIN: BLUE NILE RIVER BASIN, ETHIOPIA

[1]Mosisa Tujuba, [2]Abraham W/Michael, [3]Tena Alamirew

[1]Ambo University Institute of Technology, P.O.Box: 19 Ambo Ethiopia

[2]Hawassa University Institute of Technology, Hawassa Ethiopia

[3]Water and Land Resource Center, Addis Ababa, Ethiopia

ABSTRACT:

Hydrological processes of our globe are dynamically changing from time to time due to anthropogenic and natural effects. The population pressure, technological development and economic needs of human are forcing the alteration of hydrologic cycle in one way or another. This study focused on hydroclimatic trend analysis for this 21st century in the case of Guder sub-basin, Ethiopia. Climate and streamflow scenarios were developed to extrapolate data that was used for detecting trends in hydroclimatic series. Climate was projected by downscaling the HadCM3 output for five stations assuming A2a and B2a emission scenarios using Statistical Downscaling Model (SDSM) calibrated with the National Center for Environmental Prediction (NCEP) reanalysis data. SWAT model was used for hydrological simulation to produce synthetic streamflow data for the developed scenario. The model was calibrated (R^2 = 0.72, N_{SE} = 0.68) for the year 1992-1997 and validated 1998-2001 (R^2 = 0.73, N_{SE} = 0.69), and then used for predicting future streamflow. The synthesized climate and streamflow data were tested for long-term trend using Mann-Kendall statistical test and the magnitude of the trend was quantified by Sen's slope estimator. The result showed that precipitation in the sub-basin might significantly (α = 0.05) increase at a rate of 0.283 mm/year under scenario A2a during the year 2001-2099. Temperature may generally show significant positive trend under both emission scenarios. Maximum temperature showed increase at annual rate of 0.0217 °C for A2a and 0.0171 °C for B2a whereas minimum temperature exhibited increase at 0.0064 and 0.0038 °C per year under scenario A2a and B2a respectively in this century. The corresponding streamflow also showed a significantly (α = 0.05) increasing trend with a change rate of about 0.947 MCM/year for scenario A2a and insignificantly increasing change of rate of 0.105 MCM/year and B2a respectively. The general increase in precipitation and streamflow may favor the agriculture, hydropower generation and water supply in the study area. However, the increase in temperature may have impact on these sectors especially the agriculture. Therefore, appropriate water management policies and strategies that focus agro forestry practice, soil moisture conservation, and rainwater harvesting have to be implemented.

Keywords: Guder sub basin, Hydroclimatic trend, SDSM, SWAT model, Mann-Kendall, GCM

INTRODUCTION

Fluctuating hydrological conditions have been observed to have very significant impacts on the livelihood of humankind through ages (Balek, 1983). Alternate wet and dry periods forced people to migrate from place to place in order to cope up with the problem. More than ever, challenges faced by many countries of the world in their struggle for socio-economic development today, are primarily related to water (GWP, 2000). Hydrologic extremes (drought and flood) are the major negative outcomes of the alteration of hydrologic system. These challenges are severe in developing nations like Ethiopia, where agriculture is the primary steering system of the economy. The current food security, water supply and sanitation problems are the challenges that are directly related to water scarcity, whereas heavy storms causing flooding and land degradation due to soil erosion are related to water abundance. Areas of water scarcity cover much of the globe among which Middle, North and Eastern Africa are primarily raised (David et al., 2001)

One of the causes for alteration of water system in a watershed is climate change, which is induced mainly as a result of anthropogenic pressures like greenhouse gas emission and land use and land cover change in addition to those natural forces such as volcano, hurricanes and earth quake. It is obvious that climate change significantly affects the natural resources. However, the impact is serious on hydrologic cycle; the failure of which results in hydrologic extremes. This study focused on investigating the hydro climatic responses associated with the changing climate conditions for the case of Guder sub-basin of Blue Nile River Basin. For achievement of this objective, statically based climate downscaling and SWAT based hydrological simulation was made to extrapolate the hydrological and climatic data for long-term hydro climatic trend analysis.

STUDY AREA

Guder Sub-basin is found on the south eastern periphery of the Upper Blue Nile River Basin falling between $8^0$42'N to $9^0$54'N, and $37^0$16' E to $38^0$09' E. The area corresponds to the central Ethiopian highland where the dominant landform ranges from flat to gently sloping with undulating plains, hills and mountains with elevation range of 900 to 3230 masl. The climate of this sub-basin is generally a warm temperate type with unimodal rainfall pattern. The socioeconomic activity of the area is agro pastoral practice dominated by subsistence farming.

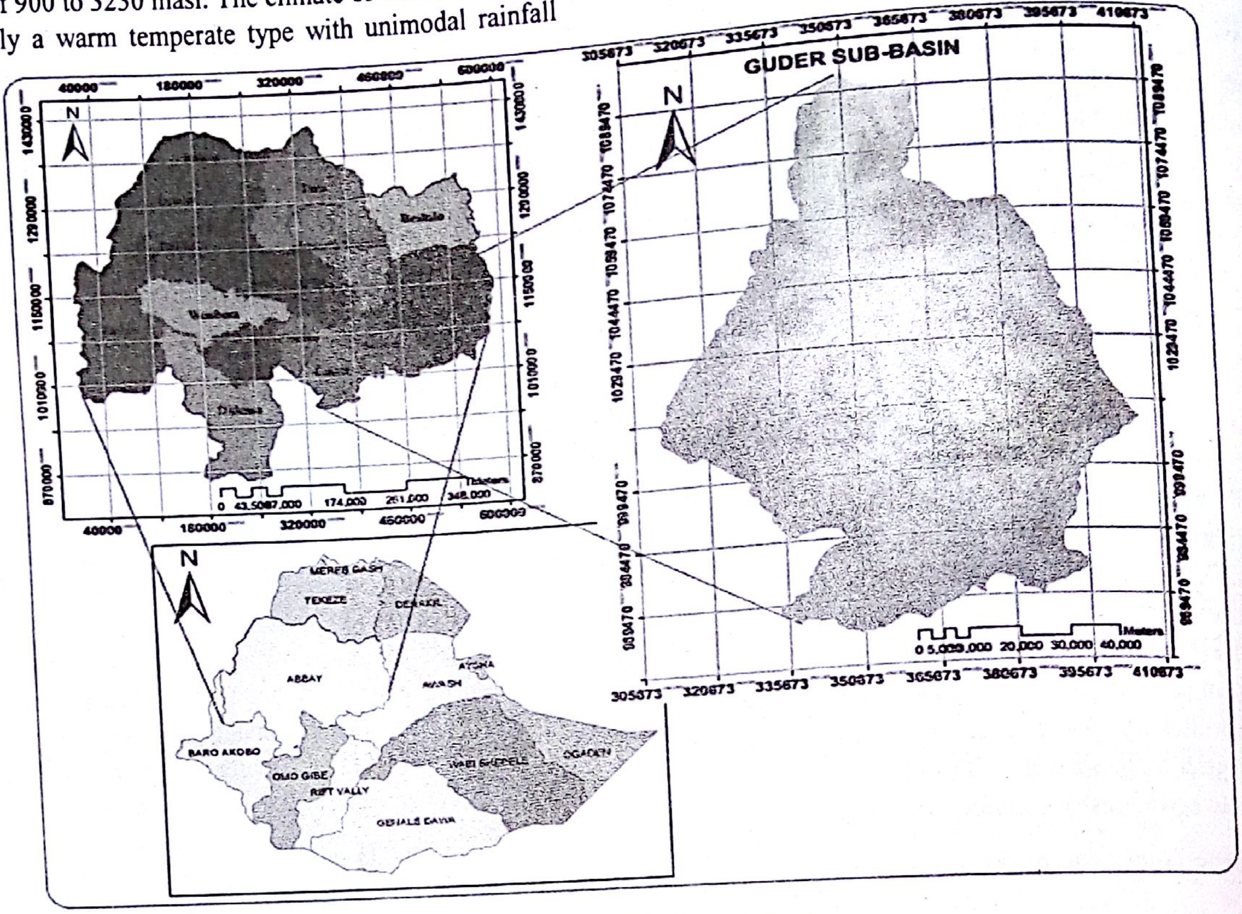


Figure 1: Location of Guder Sub-basin

METHODOLOGY

Climate Downscaling

Statistical Downscaling Model (SDSM) was used for downscaling precipitation, maximum temperature and minimum temperature using time series daily data of the year 1976-2001. The potential predictors from NCEP reanalysis data of A2a and B2a emission scenarios, were used for model calibration and validation (weather generation) for the periods of 1976-1990 and 1991-2001 respectively. The GCM predictors derived from the HadCM3 experiment under scenarios A2a and B2a were used for scenario generation. Finally the climate change was analyzed for three scenario periods: 2011-2040 (2020s), 2041-2070 (2050s) and 2071-2100 (2080s).

Hydrological Simulation

SWAT2005 interfaced with ArcGIS 9.3 was used for streamflow simulation and projection. The simulation was made using climate data of Ambo station. Sensitivity analysis demonstrates the response of the sub-basin value (flow) due to change in the input parameters. A combined Latin Hypercube (LH) and One-factor-At- a-Time (OAT) Methods of sampling which is integrated into SWAT2005 was employed for the potential input parameters screening. The analysis was made with observed flow data measured at Guder gauging station. The model was calibrated for the period 1992-1997 and validated for the period 1998-2001 for flow data Guder gauging station on the main stream; Guder River. Performance of the model was evaluated by two performance indices: the coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (E_{NS}).

w

Streamflow Projection

Change in streamflow associated with climate change was predicted by adjusting the precipitation and temperature values of the present period to the future scenarios. For this the climate scenario generated outputs of Statistical Downscaling Model (SDSM) were used to specify the impacted rainfall and temperature. Average precipitation and temperature were considered for the stream flow projection. Thiessen polygon (Shaw, 2005) method was used to calculate the areal rainfall of the study area from the five meteorological stations used in the study. The precipitation and temperature adjustment was made by assigning an appropriate percentage change under scenarios A2a and B2a for each month based on the SDSM result. SWAT makes the adjustment using eq. 1 and 2 (Neitsch et al., 2005).

$$R_{adj} = R_{day}\left(1 + \frac{adj_{pcp}}{100}\right) \qquad \text{..........................(1)}$$

$$T_{adj} = T_{day} + adj_{tmp} \qquad \text{..................................(2)}$$

R_{adj} = Adjusted precipitation falling on the sub-basin on a given day (mm), R_{day} = actual precipitation falling on the sub-basin on a given day (mm), adj_{pcp} = Percentage change in precipitation, T_{adj} = Adjusted mean temperature on a given day (°C), Tday = actual temperature (°C) on a given day, adj_{tmp} = change in temperature (°C) on a given day.

Hydroclimatic Trend Analysis:

Mann-Kendall non-parametric test (Salmi et al., 2002, Longobardi and Villani, 2009) was used to detect the long -term trend (2001-2099) of the hydrological and climatic parameters and Sen's slope estimator was used for quantification of the trend. An Excel template called MAKESENS (MAnn-KEndall test for trend and SEN's Slope estimates) provides a simplified approach towards the calculation of statistical parameters that are used for decision making on the analysis (Salmi et al., 2002).

RESULT AND DISCUSSION

The Projected Climate

The comparison made between the generated precipitation data for the baseline period and the three scenario periods indicated an overall increase in rainfall in the sub-basin for both A2a and B2a storylines. Accordingly, the mean annual increase reach about 6.44 and 3.13% by 2080s under A2a and B2a respectively (Fig. 2a and b). These results fall in the range of Bates et al., (2008) study result which showed that the increase in rainfall by 2080s may be up to 20 % in East Africa region. Ngigi, (2009) also reported that rainfall in East Africa is most likely to increase.

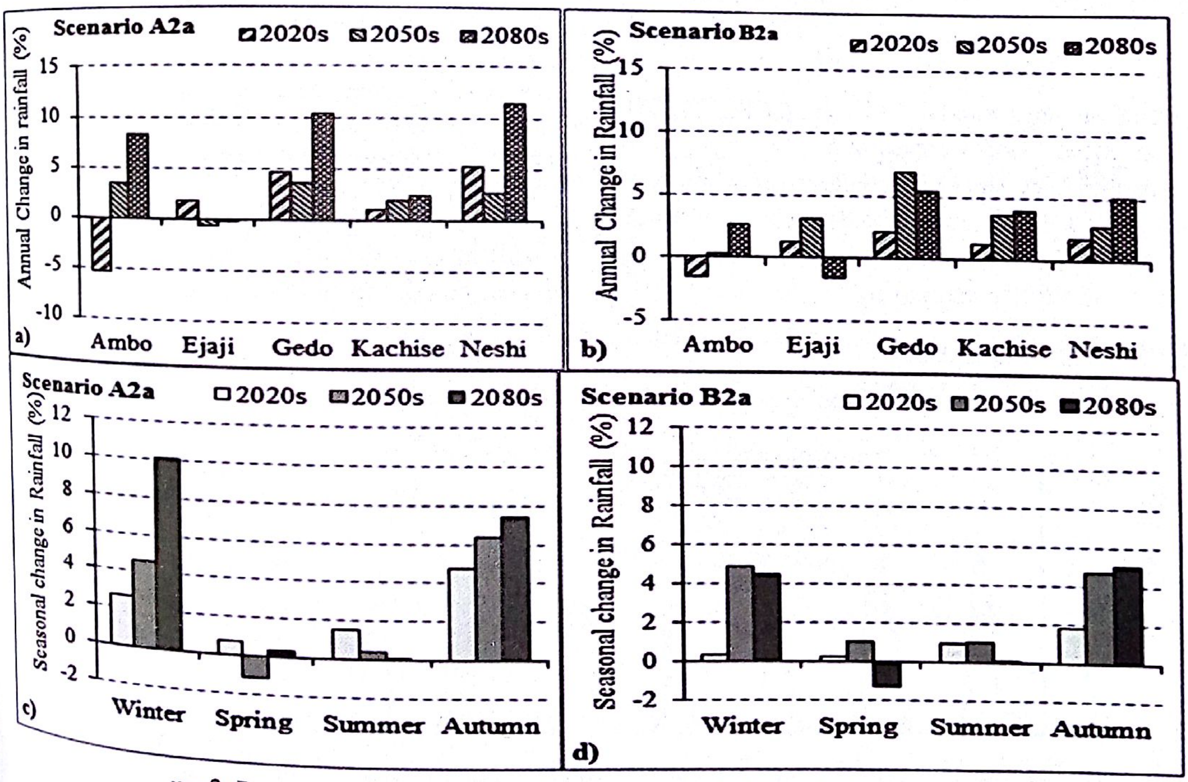


Figure 2: Percentage change in annual and seasonal rainfall at Guder Sub-basin

The seasonal rainfall showed continuous increase from 2020s through 2080s under both emission scenarios (Fig. 2c and d). Increase in rainfall during the dry season in the study area favors winter agricultural production.

The analysis result presented in Figure 3 shows that the maximum and minimum temperature in the area may show mean annual increase under A2a and B2a. For example maximum temperature may increase by up to 0.58 □ in 2020s, 1.33 □ in 2050s and 2.53 □ in 2080s for scenario A2a. Under emission scenario B2a, the maximum temperature may increase by 1.90 □ in 2080s (Fig. 3a and b). Minimum temperature also showed the same trend even if the degree of change differs. It may show increment of about 1.6 □ under scenario A2a and 1.2 □ under scenario B2a as shown in Fig. 3c and d below.

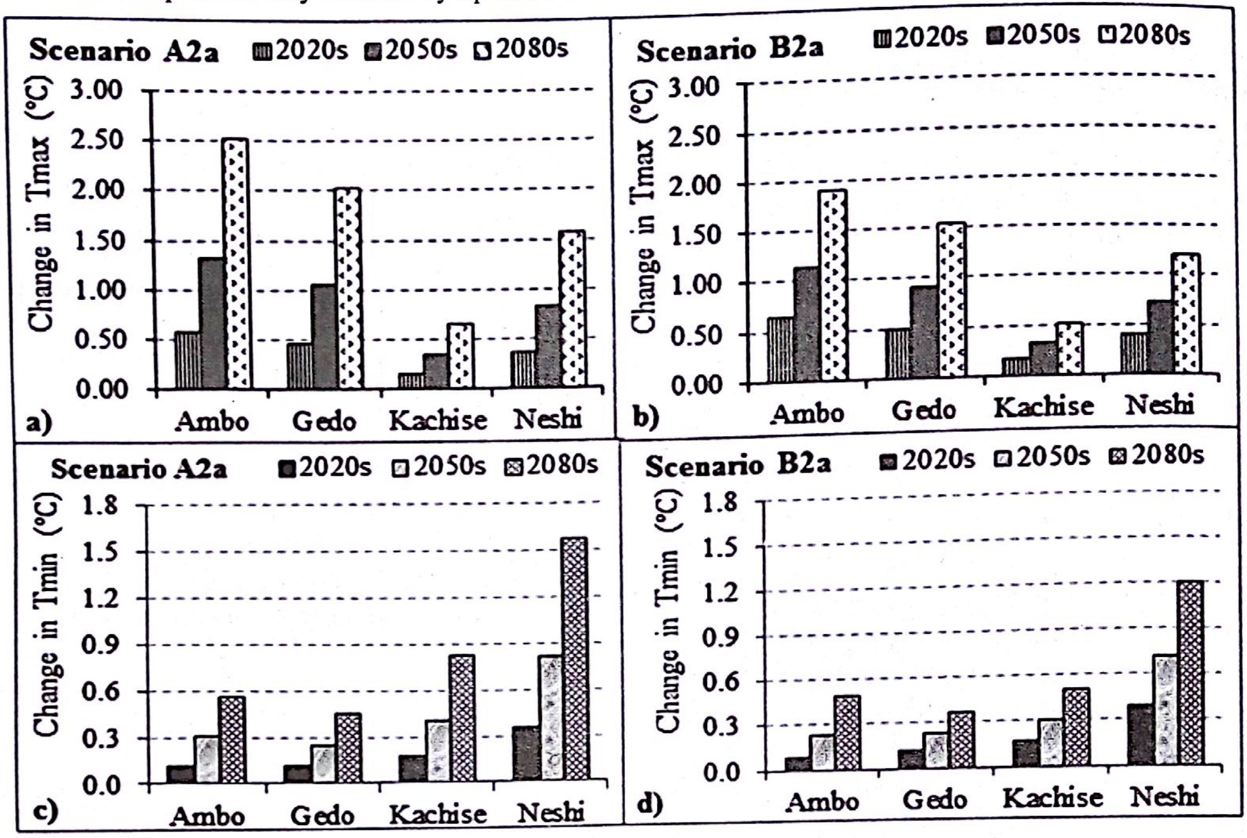


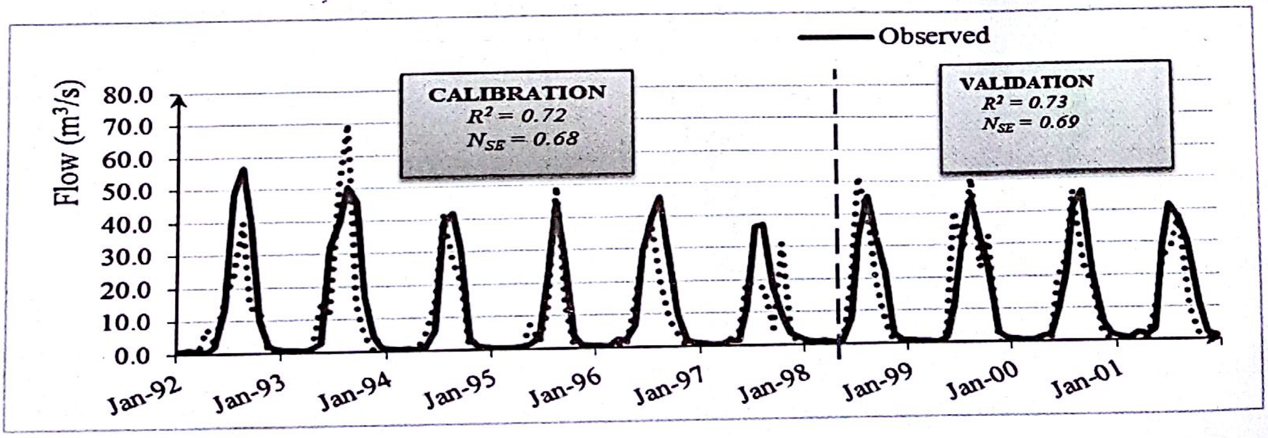
Figure 3: Change in annual maximum and minimum temperature

This result complies with the IPCC report (IPCC, 2007). It also confirms the result of study of climate impact on water resources of the Upper Blue Nile River Basin by Michael, (2012) which showed that temperature in the area may generally increase under scenario A1B downscaled by CCLM and REMO respectively.

Hydrological Simulation

The SWAT model run for the optimal set of parameter showed a good result that agrees with the observed values of the calibration (1992-1997) and verification (1998-2001) periods.

Coefficient of determination and Nash-Sutcliffe efficiency has been used as the measure of the model performance as shown in Figure 4.



Streamflow Scenario

Annual streamflow may generally show increment during 2020s and 2050s and slight decrement in 2080s for both emission scenarios. As depicted in Figure 6 below, annual flow may increase by about 3.2 % under scenario A2a and 2.1 % under scenario B2a in 2020s and this to some extent manifests the general increase in precipitation. Guder sub-basin yields about 8.26 ton/ha/year of sediment (Engidayehu, 2014). Increase in streamflow during summer season aggravates soil loss causing land degradation and siltation in the downstream dams and diversion structures.

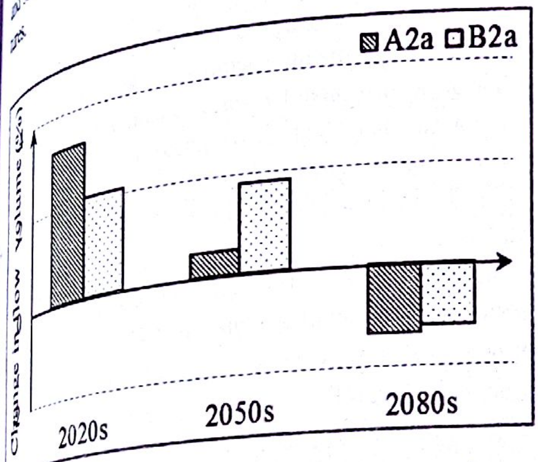


Figure 5: Projected change in annual flow volume in Guder

The increase in 2050s generally complies with the REMO result of Michael's work over the UBNRB (Michael, 2012). Despite the general increase in precipitation of about 6.5 % and 3.2 % under A2a and B2a respectively over the sub-basin in 2080s, the streamflow may show slight decrease of about 1.35 % under A2a and 1.20 % under B2a. This might be resulted due to the observed increase in temperature.

Hydroclimatic Trend

The MAKESENS result of trend test has been presented in Table 1 below. The test showed that annual precipitation of the study area showed a significant positive trend for A2a and insignificant trend for B2a at $\alpha = 0.05$ level of significance (Figure 6a). The rate of change in annual precipitation is represented by Sen's slope and the computed value is about 0.283mm/year for A2a and 0.022 mm/year for B2a.

The result also showed that maximum annual temperature showed significant increase at a rate of 0.022 °C under scenario A2a (Fig. 6c). This implies that maximum temperature might increase by about 2.17 °C for A2a and 1.71 °C for B2a by the end of this century. The increase showed insignificant rate (0.006 °C) under scenario B2a for minimum temperature as shown in Fig. 6d.

Table 1: Summary of Mann-Kendall trend test for precipitation, temperature and streamflow

Variable	Emission scenario	Test Z	$Z_{critical}$	Sen's slope (Q)	Intercept (B)	At $\alpha = 0.05$
Precipitation	A2a	2.44	1.96	0.283	1409	Significant
	B2a	0.25	1.96	0.022	1414	Insignificant
Tmax	A2a	10.48	1.96	0.0217	22.2	Significant
	B2a	10.12	1.96	0.0171	22.3	Significant
Tmin	A2a	12.10	1.96	0.00638	9.58	Significant
	B2a	10.82	1.96	0.00385	9.66	Significant
Flow volume	A2a	1.14	1.96	0.000947	1.07	Significant
	B2a	0.08	1.96	0.000105	1.15	Insignificant

The analysis result (Figure 6b) revealed that the streamflow may generally show positive trend under both A2a and B2a emission scenarios. Under scenario A2a the annual flow volume might increase at an average rate of about 0.95 million cubic meters per year. The statistical test evaluated this change to be significant at significance level $\alpha = 0.05$. The rate of the positive trend is smaller under the scenario B2a than A2a. In the case of B2a the Sen's slope was equal to 0.000105 which tells that the rate of change in flow volume is 0.105 million cubic meters per year and this is insignificant at α value of 0.05.

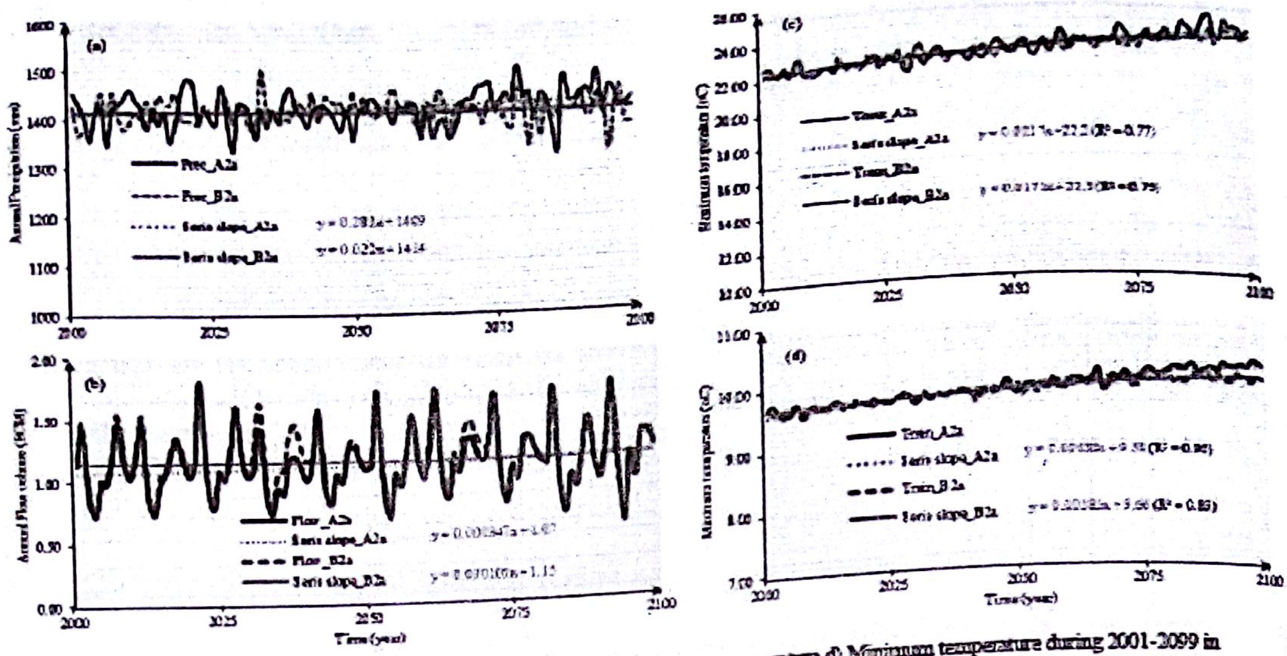


Figure 2: Long term trend in: a) Precipitation b) Streamflow volume c) Maximum temperature d) Minimum temperature during 2001-2099 in Guder sub-basin

CONCLUSION

Precipitation in Guder sub-basin is likely to increase significantly at 0.28mm/year during this century under scenario A2a and . Winter and autumn seasons may be wetter in next decades than the current condition and this may improve agricultural production during the dry months. Following increase in precipitation streamflow may show significant long term increase at a rate of about 0.95 MCM/year during 2001-2099 even if the increment happens in 2020s and 2050s. The continuous rise in temperature (0.022 °C/year) may cause decrease in streamflow in 2080s. Temperature of the area (both maximum and minimum) is likely to increase significantly under both emission scenarios.

REFERENCES

Balek, J. (1983). *Hydrology and Water Resources in Tropical Africa*. Amsterdam, 208p. Elsevier

Bates, B.C., Z.W., Kundzewicz, S., Wu and J.P., Palutikof. (2008). *Climate Change and Water*. IPCC Secretariat, Geneva, 210 pp. (Technical Paper IV)

David, M., U., Amarasinghe and I., Hussain. (2001). *Water for rural development*: Background paper on water for rural development prepared for the World Bank. Working Paper 32. Colombo, Sri Lanka: International Water Management Institute.

Engidayehu C. (2014). *SWAT based Estimation of Sediment Yield from Guder Watershed, Abay Basin, Ethiopia*. MSc Thesis, Arba Minch University, Ethiopia

GWP (Global Water Partnership). (2000). *Integrated Water Resources Management*. Background Paper No.4. Technical Advisory Committee. Denmark

IPCC, (2007). *Climate Change 2007: Synthesis Report*. Working Group contributions to the Fourth Assessment Report. Valencia, Spain

Longobardi, A. and P., Villani. (2009). *Trend analysis of annual and seasonal rainfall time series in the Mediterranean area*, Int. J. Climatol. 9p., Italy

Michael, M. (2012). *Potential Impact of Climate and Land Use Changes on the Water Resources of the Upper Blue Nile Basin*. PhD Dissertation. Freie University of Berlin

Neitsch, S.L., J.G., Arnold, J.R., Kiniry and J.R., Williams. (2005). *Soil and Water Assessment Tool Theoretical Documentation*: Version 2005. Agricultural Research Service, Texas

Ngigi, S.N. (2009). *Climate Change Adaptation Strategies: Water resource management options for smallholder farming systems in sub-Saharan Africa*. Study Report. 207p. The Earth Institute of Colombia University

Salmi, T., A., Maatta, P., Antilla, T.R., Airola, T., Amnell. (2002). *Detecting Trends of Annual Values of Atmospheric Pollutants by Mann-Kendall test and Sen's Slope Estimate: The Excel Template Application MAKESENS*. Publications on Air Quality, No.31. Helsinki

Shaw, M.E. (2005). *Hydrology in Practice*. 3rd ed. Tailor and Francis e-Library, London

The 2015 Khartoum Agreement: Is Ethiopia's Diplomatic successes or Egypt's change in Policy over The Nile?

Seid Ahmed

PhD Candidate in Comparative History

Dokuz Eylul University

Abstract

The Nile water is the major epicenter on the Ethiopia and Egyptian relation since the period of antiquity. It was highly dominated by the Egyptian who gave prior attention and became part of their national security agenda even today. To secure their water demand Egyptians used deferent strategy ranging from lopsided agreement with the Sudan as well as exploiting the unstable situations in the upper riparian states particularly Ethiopia. On the other side Ethiopia faced severe poverty as the age-old rain fade agriculture failed to be subsidized by modern irrigation system by utilizing her own water resources for a long period of time. This trend was changed after 1990s as Ethiopia embark on utilizing her water resources to reduce poverty by building dams. In many circumstance Ethiopia's plea of getting fund faced rejection due to Egyptians longhand. This scenario was changed from time to time as Ethiopia mobilized her own resourced to build dams and demanded cooperation in the ultimate utilization of the Nile waters among the riparian countries. Besides to this Ethiopia is constructing mega dams, including the Great Ethiopian Renaissance Dam (GERD), both to reduce poverty in the country as well as to link the neighboring countries, including Egypt, through electricity. The GERD is the track changer as far as Ethio-Egyptian diplomatic relation is concreted. Since the begging of the project Egypt under Mursi demanded the freezing off the project unless they will take all option of securing their historic water right. In March 2015, Egypt under Sisi came to Khartoum to sign the tripartite agreement of Nile between Ethiopia, Egypt and the Sudan. On his way, Sisi also made a historic speech on the Ethiopian parliament and assure his government will cooperate with Ethiopia over Nile. Thus this paper attempted to examine the historical and diplomatic relation between Ethiopia and Egypt as well as evaluate the Khartoum Agreement as whether the fruits of Ethiopia's diplomatic successes or whether it's the change in policy of Egypt over Nile?

Introduction

As "Egypt was the gift of Nile," the Blue Nile is the gift from the Ethiopian highlands that flow down the great Sahara Desert part of Egypt before its final end in the great water body. This made both Ethiopia and Egypt the upper and downstream countries, respectively, that shared the Nile waters since the period of antiquity that shaped and reshaped the relation between Ethiopia and Egypt until recently. The history of the relation between the two countries dated back to the 2800BC when the ancient Egyptian tired to locate the source of the Blue Nile and its tributaries. Evidences from the tombs of Titatmus III mentioned some places in Ethiopia including Adulis, Tigre and others as the sources of the river. On the other side the Aksumite king had strong contact with the Judaic world since the first millennium BC. While the introduction of Christianity in the first century further strengthened the relation as the Ethiopian Patriarch was appointed from Egypt until 1958 when Ethiopia appointed her own bishop in the hands of Emperor Haile Sillasse I.

The long aged relation between Egypt and Ethiopia was never a peaceful once. It was highly associated by military confrontation, mistrust as well as words of war due to Egypt's absolute dominance over the Nile waters until recently. Such kind of mistrust and suspicion between the two was changed time to time as Ethiopia diplomatically pushed Egypt to come to a roundtable to solve the crisis in a sense of African brotherhood.

Objective of the study

In March 2015, Egypt under Sisi came to Khartoum to sign the tripartite agreement of Nile between Ethiopia, Egypt and the Sudan. On his way, Sisi also made a historic speech on the Ethiopian parliament and assure his government will cooperate with Ethiopia over Nile. Thus the main objective of the study is to examine the historical and diplomatic relation between Ethiopia and Egypt as well as evaluate the Khartoum Agreement as whether the fruits of Ethiopia's diplomatic successes or whether it's the change in policy of Egypt over Nile?

Methodology of the study

It this study I used a comparative analysis method for evaluating the agreement by comparing this agreement with the former agreements over the Nile waters.

Nile in the Ethio- Egyptian Relations: A History

The history of the relation between the two countries dated back to the 2800BC. Since the early days the Nile factor reverberated through all aspect of the Ethio- Egyptian relation is concerned. The Nile flood became the life giver of ancient Egyptians. Such strong sentiment forced the Egyptian rulers to think that with the control of the Nile waters they could safeguard their water security. They also tried their best to unify the Nile Valley under their rule. In the twentieth century Egyptian nationalism revolved around the idea of uniting the whole Nile basin as one hydrological political unit that would be ruled from Cairo. Rulers like Khedive Ismail expanded south to the interior part of Africa with the aim of eradicating slave trade but his ultimate plans were to control the source of Nile. Because of his civilizing mission Britain blessed his southward expansion. (Bahru; 1991)

In many times Egyptians feared that the waters of Nile might possibly be blocked or diverted by the upper riparian states particularly Ethiopia. King Lalibela, in the 11th century, warned the Egyptian that he might block the river if they never stopped the persecution of Copts in Alexandria. (Haggai; 1994)

As a result many Egyptian rulers annexed Sudan and encroached the Ethiopian territories in many times. Some of the Ethio- Egyptian confrontation includes the battles of Dabarqi (1848) with Dejjach Kassa, The future Emperor Tewodros, and the battles of Gundet (1875) and Gura (1876) with Emperor Yohannis IV Who effectively defeated the Egyptian forces. (Bahru,1991; Zewde 1992)

In the latter part of the century once their military confrontation failed, Egyptian also used colonial and postcolonial times agreements to secure their water demand over Nile. In the time many agreements were signed. Of the entire earliest one was the 1902 Treaty of Addis Ababa signed between Emperor Menilek II and British on 15 May 1902 with the objective of demarcating the frontiers between Ethiopia and the Sudan. In this agreement Article III state as

His majesty, the Emperor Menilek II engage himself towards the government of His Britannic majesty not to construct or allow to be constructed any works across the Blue Nile, Lake Tana or Sobat which would arrest the flow of waters into the Nile, except His Britannic Majesty's Government and for the government of the Sudan. (Shapland, 1997)

This agreement never binds Ethiopia from the utilization of the Nile. Firstly it was not ratified by the two governments. Secondly there was discrepancy on both the Amharic and the English version and lastly as it was a colonial agreement with the intention of preventing a total stoppage not in the use or diversion of the water by Ethiopia under normal circumstance.

Four years later, in 1906 by violating the sovereignty of Ethiopia, the surrounding colonial powers of France Italy and Britain have signed the 1906 Tripartite Agreement for dividing the country into their sphere of influence as Emperor Menilek faced his first stroke that costs his life. Based on the agreement Britain planned to secure the source of the Blue Nile. (Bahru 1991)

Besides to this Egypt also made two controversial agreements with the Sudan. They were the 1929 and the 1959 Agreements. As the British attempt of uniting Sudan with Egypt failed, in 1929 Sudan motivated by Britain to maintain good relation with Egypt the two countries signed the 1929 Agreement. The agreement formally repudiated the 1959 Agreement.

In 1959 an agreement was signed between Sudan and Egypt over the appropriation of the Nile waters by excluding the other riparian states. The agreement was made on the full utilization of the Nile by allocating the lion's share (55.5BCM) to Egypt and 18.5BCM for the Sudan. Because of its exclusiveness Ethiopia downgraded the agreement by sending her communiqué to the signatories.

From international law perspective these agreements were never be applicable over the third parties including Ethiopia and other riparian countries but rather it removed a potential Sudanese threat to Egypt and it will never binding role over others. In Spite of its shortcomings Egypt used it as her legal document for securing her water demand.

In the Cold War political climate Egypt constructed and completed the High Aswan Dam with the help of the USSR. While Ethiopia got assistance from US to make Survey on the potentially of the Lake Tana for hydropower generation. The US Based engineering company studied Lake Tana for power with little cost. (Yacob 2010)

Up until 1990s the relation between Egypt and Ethiopia was full of confrontation and mistrust. After decade of confrontation and mistrust over Nile, Ethiopia and Egypt broken the silence and began to talk over Nile.

In 1993 in the president of the Transitional Government of Ethiopia and the president of Egypt republic met in Cairo to talk about the Nile in "the Framework for General Co-operation." This agreement gave more emphasis on the role of the experts from both countries on the basis of the rules and principles of international law. The controversial part of the agreement is the provision which state that neither state would do anything with the Nile that would cause "appreciable Harm" to the other. Egyptian perceived as some form of the recognition of Ethiopia that no harm principle is operational over Ethiopia. While Ethiopia consider it as no change in the status quo rather open the door for cooperation and a win win approach over Nile as Ethiopia had an absolute right of utilizing her resources for development including water.

Due to its geopolitical location as well as economic growth of Egypt both the bargaining power over Nile as well as environmental diplomacy absolutely dominated by Egypt up until recently. While Ethiopia was busy both in internal civil war as well as severe drought and famine as the age-old rain fed agriculture suffered by shortage of rain from 1960s until 1990s. In many circumstance Egypt effectively employed the instability of Ethiopia. In those days Egypt also mobilized some of the upper riparian states to establish a certain group called Undugu in order to create a mechanism of exchange of data on the Nile basin to secure her interest. As the group aimed at securing the water security of Egypt Ethiopia was never invited and was never joined to it.

In 1992 when Ethiopia was in transition, Egypt once again mobilized some of the riparian states and formed a committee for the Promotion of Development and environmental Protection of the Nile Basin (TECCONILE). TECCONILE planned for coordinating the common interests of the basin countries. Due to Egypt's dominance Ethiopia was not active member rather it became an observer state. (Rabie Elmam, 2010)

When TECCONILE officially disbanded in 1999 and paved the way for the Nile Basin Initiatives at Entebbe the voice of Ethiopia and the upper riparian stated began to get some ears. Especially Ethiopia's proposal of cooperation on the ultimate utilization of the river and the establishment of a regional body on the basin and the refute of the colonial agreements made Ethiopia and the other upper riparian states to work together. The provisions of NBI include to promote a sustainable and equitable way for sharing the natural recourse in the basin. NBI also ensure an efficient water management and optimal use of the resource; ensure cooperation and joint action between the riparian countries for their mutual benefits and to eradicate poverty and promoting economic integration among the riparian states.

NBI became the first venue of bringing together all the riparian states and has taken significant steps to implement many concrete strategies for sustainable development on the basin. As the balance of power of Egypt over Nile changed, in many NBI meetings Egypt demanded keeping the status quo of securing her 'historic right' as well as demanding a veto powers which was hardly accepted by the member states including Ethiopia rather they proposed a win win approach and sharing the view of equitable utilization of the resource.

After decade old a series of diplomatic negotiations the Entebbe declaration endorsed and the Cooperative Framework of Agreement, CFA, was open for a year to be signed by member states. In March 2010 the CFA was signed in Entebbe, Uganda, by six member states of Ethiopia, Kenya, Tanzania, Rwanda, and Burundi and call others to put their signature. Instead of signing both Egypt and Sudan refused it even Egypt frozen her membership of the NBI in 2010. As two-third of member state signed the CFA, it absolutely abrogated the colonial time agreements of Nile and demanded the signatories to ratify it in their parliaments in a short period of time.

In the meantime the 2011 Arab Spring changed the Middle East scenario including Egypt. The revolution ended by the downfall of the longtime president Hosni Mubarak from Power and the coming of Muslim Brotherhood under Muhammad Mursi with a landslide democratic election. The same year the Ethiopian Prime Minister Meles Zenawi declared the beginning of the Grand Ethiopian Renaissance Dam Project in the Northwest Part of the Country in order to produce more than 6000MW hydroelectric power over the Blue Nile near the Sudanese Border.

The Road to Khartoum

Until recently many Egyptian rulers have strong words as far as the Nile water is concerned. In 1979 Anwar Sadat said that "the only matter that could take Egypt to war again is water" to indicate about the issue of Nile as his prior agenda. In the same instance Boutros Boutros Ghali, the Foreign Minister of Egypt, touched the issue of Nile as "the next war in our region will be …over Nile, not politics." While Hosni Mubarak gave Nile as his top priority of his administration allocated a huge amount of resources to his water security policy.

Even the democratically elected Mursi also made a speech as "we will defend each drop of the Nile with our blood." Mursi, on the eve of his downfall, also live-aired that his country might use all options to secure her water security. As opposed to this the current Egyptian president Abdulfatah El Sisi's government accepted the right of development of the upper riparian countries including Ethiopia and committed his government to solve the Nile crisis politically by putting his signature in the trilateral agreement of Khartoum in March 2015. Now let's see the long road that reached to Khartoum between Ethiopia, Sudan and Egypt to deal for the equitable share of Nile between the lower and upper riparian states.

The basic factor for the signing of the Khartoum agreement is the constriction of the GERD in Gubba since March 2011. Even though Ethiopia mobilized her own resource to realize the project and called the downstream countries to share the burdens and benefits of the project as the project planned to produce power and link the power hunger region through electricity including the poor Egyptian villages. It also intended to reduce the water lose in the desert, impact of flood and sedimentation in the High Aswan Dam as well as to regulate the constant flow of water throughout the year.

Ethiopia's continuous plea of the wide range of the benefit of the dam fails on deaf ear and Egyptians reacted in differently. Initially they demanded the freezing off the project unless they would take action. As Ethiopia continued the construction they also raised issues on the technical and the quality of the function of the dam as well as they also demanded the joint administration of the dam. To all Egyptian worries Ethiopia reacted the continuity of the construction per its plan and Ethiopia as a sovereign state has the capacity to construct as well as to administer many mega projects including GERD.

On the Ethiopian part of diplomatic effort for the international community and to make things clear Ethiopia proposed and accepted for the establishment of an international panel of Experts to study the pros and cons of the dam. In the meantime Ethiopia also invited the Egyptian public diplomats to Addis Ababa and clarified the mutual benefits of the dam for both countries even though Egypt was in crisis in 2011.

After the revolution, Ethiopia also continued her diplomacy with the newly elected government. After a series of diplomatic maneuverings, Ethiopia's proposals were accepted by Egypt to discuss at the capital of Khartoum. In 2013 and 2014 three ministerial level meetings were held between Ethiopia, Sudan and Egypt over the dam. In all these meetings Ethiopia explicitly justified the basin wide benefits of the project to the continent to provide electric power with lowest cost for the power hunger African villages including Egypt and the Sudan. In the middle of the session Sudan supported the project while Egypt refused to come to agreement.

After taking power the Sisi government revised Egypt's position and ready to meet with Prime Minster Haile Mariam Desalegn. On the side line of the 23rd African Union summit of Equatorial Guinea, Malabo, the two head of states met for the first time face to face and assured to take political action over Nile and proposed to meet in Khartoum in March 2015.

On 25 March 2015 the two leaders flew to the capital of the Sudan, Khartoum and agree to solve the issue politically and approved by putting their signature in the sense of African brotherhood. On the next day, President Abdulfatah El Sisi has made a historic speech in front of the Ethiopian parliament. In his speech the president confirmed that his government is fully committed to work together in the sense of African brotherhood.

Discussion on the 2015 Khartoum Agreement: is Ethiopia's diplomatic success or Egypt's change in Policy over Nile?

Initially Ethiopia became an observer on the NBI while Egypt became an active participant. After ten years of negotiation the status of the two changed as Ethiopia successfully mobilized the upper riparian states Egypt freezed off her membership in 2010 after the NBI members arrive at Entebbe to sign in the CFA. On the first day six member states of Ethiopia Kenya, Rwanda, Tanzania, Burundi and Uganda put their signature on the CFA while Egypt and the Sudan rejected as the provision allowing the relocation of the Nile water quota and the disregard of the 1959 Agreement.

On the other side Ethiopia's voice got hearing ears in many regional and international issues. Since 2006 Ethiopia under the late Prime Minster Meles Zenawi became Africa's chief negotiator. In many G8 meetings Africa was represented by him. Particularly in 2009 the UN organized the impact of climate change summit of COP15 at Copenhagen, Denmark, Ethiopia defended that climate change affected Africa and requested compensation for damage while Africa is suffering from it. In the summit the Ethiopia's proposal of the use of renewable energy and the carbon trade to reduce poverty in Africa have have an international acceptance. This is one of the big diplomatic successes of Ethiopia that attract the eyes of some financial institutions to support some small dam projects.

The other diplomatic success was the coming of the current Egyptian president in a round table after a long and painstaking diplomatic effort on the side of Ethiopia. In the Malabo Declaration of 2014 by which both Addis Ababa and Cairo agreed to define their relation in the ultimate utilization of the Nile by developing mutual trust and they also agree to establish a tripartite technical committee and to select an international consulting firm to study the dam's environmental, hydraulic and economic effects on the downstream countries.

The best success of Ethiopia's diplomatic effort bore a fruitful fruit at Khartoum on 25 March 2015 when the three head of states reached a consensus over GERD. The leaders said that the declaration principles would pave the way for further diplomatic cooperation on the GERD.

Since the very beginning Ethiopia's position was not causing a significant harm over Nile rather to exploit the resource to reduce poverty in the country in a sense of African brotherhood said the Ethiopian primer. While Ethiopian stand is also supported by Egyptian president as "You will develop and grow and I am with you." He further stated that " we could have lived for years in dispute and doubt but we have opted for cooperation and trust" to justified his position as his government was on the wake of changing policy over Nile and turned his eyes to African brotherhood instead of pan Arabism policy of Egypt. This agreement to avoid conflict and to establish mutual trust and cooperation among the three countries over the Nile waters was positively recognized by many international communities including the US.

In the preamble of the agreement it gives priority for respect rather than binding over Nile. The provisions of the principles clearly accepted by the signatories as it give a wide range of benefits to them by avoiding conflict in the basin. It also gives propriety to the downstream countries to get electricity with low cost generated from the dam; ensure a mechanism for resolving conflicts as well as provide compensation for the damage. In either case they agree to solve any mistrust by referring to the head of state.

Conclusion

After along diplomatic effort Egypt under Sisi became the first in changing its age long rigid policy over Nile and opened the door for discussion with the upper riparian counties. Following the Khartoum Agreement Egypt also restarted negotiation with NBI and now reconsidering the CFA. President Sisi became the first Egyptian president in making historic speech on the Ethiopian parliament. This imply that Egypt under Sisi is changing its policy regarding GERD, toning down its rhetoric on international level and heading toward dialogue and reconciliation due to Ethiopia's strong diplomatic efforts in the last two decades. The key for this success is Ethiopia's clear foreign policy towards the surrounding states of cooperation over the Nile as well as the alarming increment of Ethiopia's bargaining power in both regional and international politics as well as her own double digit economic growth facilitated the mobilization of her own resources for the construction of Mega projects. To the end the century old Egyptian dominance over Nile was overtaken by less than two decades Ethiopian diplomacy. Thus it can be conclude that the 2015 Khartoum Agreement over Nile is one of the fruits of Ethiopian diplomats in bringing Egypt to a roundtable as well as the effectiveness's of Ethiopian foreign policy in the last two decades. As heavy machineries and many thousands of workers working day and night in the Guba, the dam is now became a reality. Thus the downstream countries have no other choice but to cooperate to share the fruits out of it.

Reference

Bahru Zewde. 1991, *A Modern History of Ethiopia.* AAU Press

Bulloch and Darwish. 1993, Water *crisis: Coming conflict in the Middle East.* London

Danel Kinde "Egypt and the Hydro politics of the Blue Nile River." In *Addis Tribune* 7 August, 1999.

Haggai Erlich, *Ethiopia and the Middle East.* Syracuse University Press. 1994

Rabie Elmam, Hosam, 2010. "Egypt and the Collective Action Mechanisms in the Nile Basin" in Terje Tevedt (ed.), 2010 *The River Nile in the Post-colonial Age: Conflict and cooperation among the Nile Basin Countries.* L B Tauris

Shapland, Greg. 1997. *Rivers of Discord: International Water Dispute in the Middle East.*

London

Terje Tevedt(ed.), 2010 *The River Nile in the Post-colonial Age: Conflict and cooperation among the Nile Basin Countries.* L B Tauris

Waterbury, John. 1979. *The Hydro-politics of the Nile Valley.* Syracuse.

Yacob Arsano. "Institutional Development and water management in the Ethiopian Nile" in Terje Tevedt(ed.), 2010 *The River Nile in the Post-colonial Age: Conflict and cooperation among the Nile Basin Countries.* L B Tauris

__________2001 "Legal and Institutional Predicaments of Cooperation in the Nile Basin"

A paper presented at the Seminar Organized by the Center for Security Studies and Conflict Research, Zurich 30th January.

__________2000 "The Nile Basin: Upstream Perspective of Cooperation in the New

Millienum" A paper presented at the Nile 2002 Conference, Addis

Ababa, 6-30 June.

Zewdie G/Sellassie, 1991. *Yohannes IV. A political Biography*. Oxford

__________2000 "The Nile Question In a New era of Cooperation among

Riparian States" proceedings of the Nile 2002 Conference, Addis Ababa, 28 June 2000.

Assessment of Drinking Water Quality in Mercato, Addis Ababa

By selamawit Mulugeta

Email: - Smulugeta101@gmail.com

Cellphone: - +251-912-65-61-93

Abstract

While water is released from treatment plant for consumption purpose it does not embrace anything harmful and objectionable to human health. But due to the complex interaction of the distribution system with the environment quality of water may deteriorate. This study was conducted in Mercato, Addis Ababa which is the largest market place in the country. Since the study area is very slum, crowded and serves as center for commercial activity the residents are forced to lead their day to day life activity in a small place.

In the previous year's water quality assessment at different place within the distribution system was not the basic concern for many water sectors. The core objective of this research was contributing data for preparation of drinking water quality assessment database for Addis city sub-city especially for Wereda 1 and Wereda 8. This objective was achieved through assessing water handling practice and sanitary condition (with the help of questionaries' and observation), assessing knowledge, attitude and practice of the community towards water quality at their tap (with the help of questionaries'), and assessing the status of drinking water quality (with laboratory analysis) and analysis of its health impacts. After collecting all necessary data concerning each study parameters and environmental conditions from checklist, laboratory and observation results were summarized by Microsoft Excel and analyses of variance (ANOVA) at 95% confidence level were used to determine the significance differences by using JMP program version5.

All the result from the study put together on the following conclusion. In the study area most of the people does not expect deterioration in quality of drinking water at their tap. This indicates that the level of knowledge on water quality deterioration has been significantly low. Those drinking water pipes having leakage problem caused potential hazard to contaminate the water by solid and liquid waste due to poor management of waste by the community. Water at taps was grossly contaminated with Nitrate and Ammonia than water tested from Treatment plant and Reservoir. This result an increase in Turbidity which reduces performance of disinfection process then leads to continued existence of water associated diseases causing organisms. Poor domestic waste disposal, interconnection of drinking water pipes with sewer and presence of leaky pipe which result cross contamination with the surrounding seem to contribute largely to the higher level of bacterial contamination of water in the distribution systems.

Key words: - Tap Water quality, Distribution system, Waterborne disease, Mercato,

INTRODUCTION

Water quality is generally defined by a collection of upper and lower limits on selected possible contaminants in water. This is evaluated by using water quality indicators (parameters or classes) which can be classified into three broad categories: physical, chemical and biological. Within each class, a number of quality variables are considered. The acceptability of water quality for its intended use depends on the magnitude of these indicators and is often governed by regulations.

STATEMENT OF THE PROBLEM

In slum places where liquid and solid wastes are not properly managed deterioration in quality of water may be a major problem. Due to this checking quality status of water by indicator bacteria such as total coliforms, fecal coliforms and/or fecal streptococci is crucial.

In the study area, inappropriate liquid and solid waste management are the major problems and this greatly destructed the image of the area. As a result, if there is a possibility to join leaky pipes, this may contribute to deterioration of water quality in the distribution network.

So this research was done to check and relate the quality status of water from treatment plant, to consumer tap.

OBJECTIVE OF THE STUDY

GENERAL OBJECTIVE

The general objective of this study was to contribute data for preparation of drinking water quality assessment database for Addis city sub-city especially for Wereda 1 and Wereda 8.

SPECIFIC OBJECTIVES

- To assess water handling practice and sanitary condition;
- To asses, knowledge, attitude and practice of the community towards water quality at their tap
- To assess the status of drinking water quality and its health impacts,

CHAPTER TWO

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

Addis Ababa, the capital city of Ethiopia has ten sub-cities. Addis city sub-city is one of them which consist of 10 Weredas. Among this the study focuses only on two Weredas, Wereda 1 & Wereda 8, which embraces a total of 9,434 residential units according to CSA, 2010.

MATERIALS

SOURCE OF DATA

Primary and Secondary data

EQUIPMENTS USED

Quantitative spectrophotometer, comparator or colorimeter and pH meter, Sampling bottle, taste tubes, Diurnal tubes, Knife/spoon, Distiled water, Incuabation machine, Sterilization machine, Referagarator, Spectrometer, and Pipet.

METHODS

DATA COLLECTION

DATA COLLECTION TECHNIQUES

Literatures from published and unpublished sources, questionnaire, informal discussion, and visual inspection were the major data collection techniques.

SAMPLE SIZE DETERMINATION FOR ASSESSMENT OF KAP

Total number of residence in the two Wereda's was 9434; from this total population sample was determined by using the following statistical formula (CochranWG, 1977).

$$n(i) = \frac{N*Z^2*P*Q}{W^2*(N-1) + Z^2*P*Q}$$

n (i) ....sample household

N...total number of house hold

P............... proportion (50%)

Q............1-P

Z.............95%confidence interval (1.96)

W...............5%

Using this total of 370 household was selected to fill the questionnaires.

SAMPLE SELECTION FOR WATER QUALITY ANALYSIS

As the basic assumption that Water quality may not vary at a nearby distance (WHO, 2001) 5% of total sample was taken as a representative sample (19 tap). Additionally water sample from the nearby reservoirs represented by sampling code of R_1 and R_2 were taken. So total of 21 sampling points were selected then laboratory analysis was done in triplicates.

SAMPLE HANDLING AND REAGENTS USED

REAGENTS USED

Lactose broth, BGB(Brilliant green bile), Nitrate and nitrite reagent, Nessler and DPD(Diethyl-Phenylene-Diamine)

SAMPLING TIME, STORAGE AND TRANSPORTATION

comparator and sampling kit were used. The collected samples were made to reach to laboratory within less than 8 hours. Residual chlorine were analysed at time of sampling.

STATISTICAL DATA ANALYSIS

All results were summarized by Microsoft Excel and analyses of variance (ANOVA) at 95% confidence level were done by using JMP program version5.

...LTH IMPACT ASSESSMENT

Based on the criteria shown in Table 2.1 impact assessment was done.

Table 2.1 criteria used for Appraisal of health impacts (Espinoza, 2002)

Character (C)	Negative (-1)	Neutral (0)	Positive(1)
Significance (S)	High (3)	Medium (2)	Low(1)
Disturbance(D)	Important(3)	Regular(2)	limited(1)
Occurrence(O)	Very probable(3)	probable(2)	unlikely(1)
Extension(E)	regional(3)	local(2)	specific(1)
Duration(D)	permanent(3)	Medium-term(2)	Short-term(1)
Reversibility(R)	Irreversible(3)	Partial(2)	Reversible(1)
Total	18	12	6

Significance: - is the superiority of the affected environment, and was determined with the help of Table 2.2

Table 2.2 Appraisal of impact significance

Extension	Specific	1
	Partial	2
	Extensive	3
Time of occurrence	Immediate	3
	Medium-term	2
	Long-term	1
Persistence	Temporary	1
	Permanent	3
Reversibility	Impossible	4
	Long-term	3
	Medium-term	2
	Short-term	1

High…….≥ 9, Medium….. 5- 8 and Low…………..≤ 4

Based on this environmental risk is done by the following categorization

Total impact=C* (S+D+O+E+D+R)

Negative (-)

Sever…….≥ (-) 15, Moderate… (-) 9- (-) 15, Compatible…….≤ (+) 9

Positive (+)

High…….≥ (+) 15, Medium……… (+) 9- (+) 15 and Low………≤ (+) 9

CHAPTER THREE

RESULTS AND DISCISSION

SANITARY INSPECTION

BASIC SANITATION

More than half of the community (83%) use communal latrine.

ENVIRONMENTAL SANITATION

32% of household units have big sack (which serves as dustbin) at a selected place for solid waste storage inside their garden. But most of the people about 68% residents were dumping out the waste materials along the streets and on open spaces.

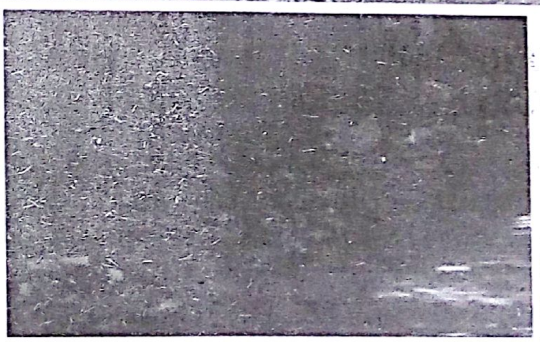


Fig 3.1 solid waste disposal in the community: (a) improper waste handling at common storage points (b) damping of solid waste on the street

Like the Solid waste Liquid waste in the study area were not managed properly. From the checklist result about 48% has no liquid waste drainage system this result bad smell on the area.

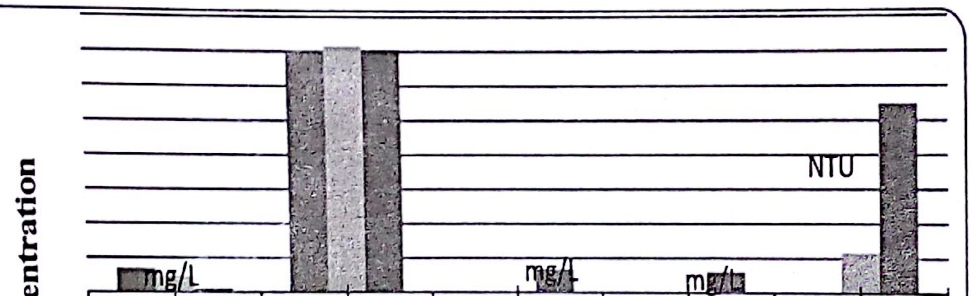
Fig 3.2 drainage and pipe lines crammed by stones and other solid wastes

CONSUMERS KNOWLEDGE, ATTITUDE AND PRACTICE REGARDING TO WATER QUALITY

Most of the people (71.6%) do not expect that their tap water would be contaminated. This was due to their inadequate knowledge on water quality deterioration.

PHYSICO-CHEMICAL WATER QUALITY ANALYSIS OF WATER SOURCE, RESERVOIR AND TAP WATER

The result of this study on water quality at Water source, Reservoir and Consumers tap for all selected parameters is presented under:-



	R.cl	Ph	Ammon	Nitr	Tur
Treatment plant	0.7	7	0	0	0
Reservoir	0.466666667	7.167	0	0	1.178
TAP	0.102631579	7.06386	0.677	0.602	5.49

Fig 3.3 Graphical representation of parameters at Treatment plant, Reservoir and Consumer tap

BACTERIOLOGICAL WATER QUALITY AT SOURCE, RESERVOIR AND TAP

Due to the well efficient disinfection process and proper management of treatment plant treated water from Geffersa water treatment plant were wholesome. Bacteriological water quality analyses results prove that water at source were free from both TC and FC. And as that of water treatment plant water from reservoir were wholesome. The value of TC and FC in both reservoirs R_1 and R_2 were found within WHO (2001) guideline and ES (1998). But 70% household water samples from tap in Wereda 1 and 67% water samples in Wereda 8 indicate presence of total coliform. And on average of 42% of tap water sample shows existence of thermo-tolerant (fecal) coliform.

HEALTH IMPACT ASSESSMENT

The significant of impact for all tested parameters was greater than 9 so all the parameters are highly significant for the entire environment. In addition taking this as input the overall health impact was categorized under severe impact.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATION

CONCLUSION

In the study area most of the people does not expect deterioration in quality of drinking water at their tap. But Water at consumers tap was grossly contaminated with Nitrate and Ammonia than water tested from Treatment plant and Reservoir this result an increase in Turbidity which reduces performance of disinfection process. That way why bacterial indicator was seen as water moves from treatment plant to tap. Consequently the result from health impact assessment of drinking water on the study area shows that usage of this water for consumption purpose has a severe impact on the community's health.

RECOMMENDATIONS

Regular inspection of sanitary and hygienic aspects and strict control and appropriate management of the distribution system for prevention of contamination must be done.

Solid and liquid wastes must be managed properly and frequency of waste removal must be increased and private involvement must be appreciated.

Public Awareness and Involvement must be practiced

The present work is limited to few physico-chemical parameters and sampling frequency. Therefore, year round sampling and analysis of additional parameters of water quality must be undertaken.

REFERENCES

Cochran WG (1997), sampling techniques, John wiley and sons, Newyork

CSA (2010),central Statics Agency number of total household for each sub-city

Ethiopian standard and WHO guideline values, (1993,1998), Drinking water guideline values, [Nov 2012], http://www.lenntech.com/drinking-water-standards.htm

Guillermo Espinoza (2002), management and fundamentals of environmental impact assessment, ch7

WHO, (2001), Guidelines for drinking water quality, Vol.2. World Health Organizations, Switzerland, Geneva.

Analysis of stable Isotopes for the Estimation of mean residence time in the Chemoga meso-scale Catchment, Abay/Upper Blue Nile basin.

Sirak Tekleab Gebrekristos

Hawassa University, Institute of Technology, School of Water Resources and Irrigation Engineering, P.O.Box 05, Hawassa, Ethiopia.

E-mail: siraktekleab@yahoo.com

Abstract

The main objective this study is to estimate the mean residence time in the Chemoga meso-scale catchment (358 km^2) Abay/Upper Blue Nile basin, Ethiopia. Samples of precipitation on bi-weekly and streamflow on weekly basis were collected and their isotopic concentrations have been analysed during a period July 2009 - August 2012. The black box models and Sine wave regression model have been used to estimate the mean residence time. The results of the analysis indicate that both methods give comparatively similar mean residence times varies between 3-4 months. These results suggest that the water exhibit young age of shallow groundwater storage in this agricultural dominated catchment. This short mean residence time further depict limited groundwater storage that the river could not produce sustained baseflow during the drought year. Consequently, catchment management is recommended aiming at increasing of soil water retention and recharge to enable sustainable development in this agriculturally dominated catchment.

Key word: Stable Isotopes, Mean residence times, Black Box models, Chemoga meso-scale catchment, Abay/Upper Blue Nile basin.

Introduction

The mean residence time or transit time is the average time water spends in the subsurface system before it reaches a specific point along its flow path such as at the catchment outlet (McGuire et al., 2002). The mean residence time is a fundamental catchment descriptor that reveals information about storage, flow pathways and source of water in a single characteristic (McGuire, and McDonnell, 2006). Furthermore, it enable to gain a better understanding of flow path heterogeneities (Dunn et al., 2007), and to get insights into the internal processes of hydrological systems (Wissmeier and Uhlenbrook, 2007, Hrachowitz et al., 2011). The determination of the mean residence time has much practical significance for water resources management by indicating the age of water stored in the subsurface system Uhlenbrook et al. (2002), inform how catchment retain and release water and solutes that in turn set biogeochemical conditions and affect contamination release or persistence (McDonnel et al., 2010).

Thus, in recent years the use of isotope tracer techniques to understand mean residence times (MRTs) and residence time distributions (RTDs) have received considerable interest (Rodgers et al., 2005; McGuire and McDonnell, 2006; Hrachowitz, 2009). However, the use of stable environmental isotopes for water resource management has limited application in Africa. Few studies use stable isotopes for identifying runoff components in Africa. For instance in Ethiopia Tekleab et al. (2014) used stable isotopes to characterize their temporal and spatial variation and for identifying runoff components on a seasonal time scale in the headwater catchments of the Abay/Upper Blue Nile basin. Kebede and Travi (2012) analyzing the composition of meteoric water in Ethiopia using environmental isotopes. Munyaneza et al. (2012) applied stable isotopes and chemical tracers to separate the runoff hydrograph into three components in the Migna catchment Rwanda. Mul et al. (2008) used stable isotopes and chemical tracers for hydrograph separation in the Makanya catchment Tanzania.

Nevertheless, the usefulness of stable isotopes for mean residence time estimation is largely unexplored research in Africa. The objective of the present study is to estimate the mean residence time in the Chemoga meso-scale agriculturally dominated catchment, in the Abay/Upper Blue Nile basin.

Material and Methods

Study area:

The study was performed in the Chemoga headwater catchment Abay/Upper Blue Nile basin (358 km^2), located in the North Ethiopia. It is a mountainous catchment with elevation ranging from 3999 to 2400 m a.m.s.l (see figure 2.1). The climate in this catchment has a distinct seasonality with three seasons:

(i) Summer as the main rainy season from June to September, (ii) winter as the dry season from October to February, and (iii) spring as the short rainy season from March to May (NMSA, 1996). The long term average annual temperature over the period of 1973-2008 at Debre Markos weather station is about 16.3°C. The mean precipitation ranges between 1342-1434 mm a^{-1} (1973-2010) in the lower and upper part of the catchment that generates annual streamflow of about 588 mm a^{-1}.

2.2 Data:

Streamflow data set is based on manual water level measurements (daily at 06:00 a.m. and 06:00 p.m.) at Chemoga gauging station from 2009□07□01 to 2011□08□31. Based on the stage discharge relationships rating curve were developed using regression model. Networks of four manual rain gauges and precipitation sampling locations for the isotope analysis at (Debre Markos, Enerata, Rob Gebeya, and Fana Choke) have been established in July 2009. Consequently, daily precipitation data were collected from these stations over the same period as the stream flows. Similarly, the mean daily minimum and maximum temperature data at Debre Markos station were obtained from the Ethiopian National Meteorological Agency.

The catchment average precipitation amount, catchment mean annual temperature, potential evaporation, and isotopic composition of precipitation were computed using the Thiessen polygon method.

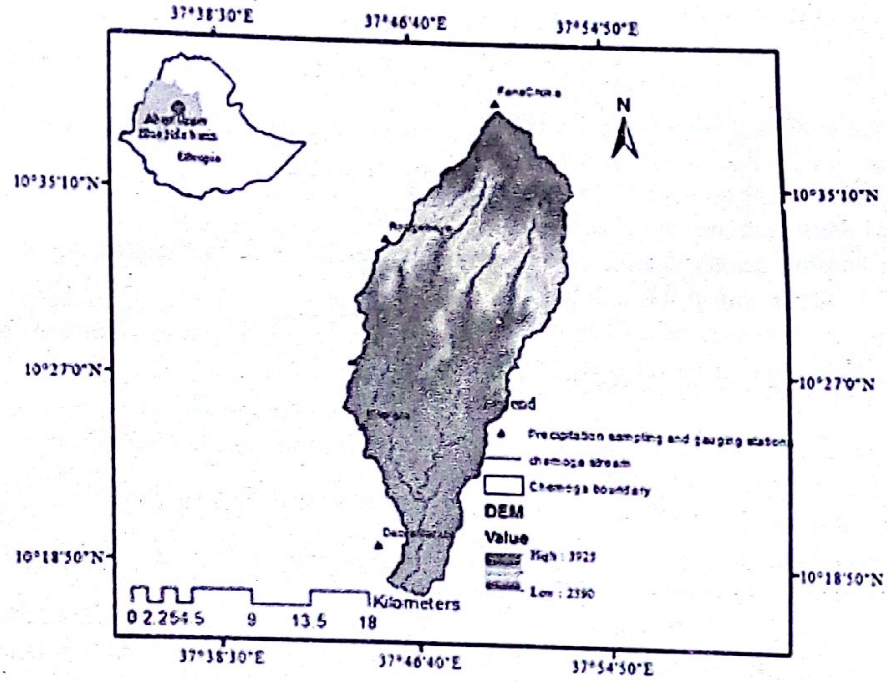


Figure 2.1: Location map of the study area: in the inset Ethiopian map, the red dot indicate the location of Chemoga catchment within the Abay/Upper Blue Nile basin.

Table 2.1 Description of isotope sample locations and total number of samples taken during the investigation period (Aug. 2008-Aug. 2011).

Sample type	Location name	Abbreviation	Elevation (m a.s.l)	Number of samples	Investigation period
Precipitation	Debre Markos	P-DM	2515	58	Aug. 2008- Aug 2011
Precipitation	Enerata	P-EN	2517	24	July 2009- Aug. 2011
Precipitation	Rob Gebeya	P-RG	2962	53	Oct. 2008-Aug. 2011
Precipitation	Fana Choke	P-FC	3993	41	July 2009-Aug. 2011

Field measurements and sampling

To characterize the spatial and temporal variability of stable isotope composition in precipitation and streamflow, field investigations have been undertaken, from August 2008 until August 2011. At four different locations, plastic funnels were used to collect the precipitation samples for the analysis of isotopic signature in precipitation. The samples were collected on bi-weekly basis.

The rainfall sample collectors have a capacity of 10 liters fitted with vertical funnel with a mesh on top to avoid dirt and a long plastic tube to minimize evaporation out of the collection device according to IAEA (2009) technical procedure for sampling. During sampling, the water was filled into 2 ml glass bottles and closed immediately to avoid fractionation due to evaporation.

Laboratory analysis

All water samples were analyzed at UNESCO-IHE (Delft, The Netherlands) using a LGR liquid-water isotope analyzer during 2010 - Oct. 2011. The stable isotopic composition of oxygen-18 and deuterium are reported using the δ□notation, defined according to the Vienna Standard Mean Ocean Water (VSMOW) with $\delta^{18}O$ and $\delta^{2}H$. The accuracy of the LGR liquid-water isotope analyzer measurements was 0.2‰ for $\delta^{18}O$ and 0.6‰ for $\delta^{2}H$, respectively.

Methods:

To determine the mean transit time of water, the temporal variation of the measured tracer input concentration i.e. precipitation, is used to calculate the tracer output concentration of streamflows at the outlet (i.e. which, in turn, is compared with the concentrations measured in the output from the system). The relationship between input and output concentrations is described by the well known convolution integral (see equation 2.1). For this study "FLOWPC" described in detail in Maloszewski & Zuber (1996) is applied. The selection of the model depends on the hydrogeological conditions in the groundwater system under consideration. The dispersion, piston flow, exponential, and exponential-Piston flow models are available. For the present study only the exponential and piston-flow models are used with the assumption that in most cases the streamflow is generated from the shallow groundwater.

A detailed description of the model applicability can be seen in more detail in Maloszewski & Zuber (1996).

$$\delta(t) = \int_{-\infty}^{t} \delta_{in}(t')g(t-t')dt'$$

Eq. 2.1

Where, d(t) is the output ^{18}O signature, t′ is an integration variable that describes the entry time to the system, t is the calendar time, d_{in} is the input ^{18}O signature to the system (i.e., input function), and g(t-t′) is the residence time distribution or system response function, which is the travel time probability distribution for tracer molecules in the system.

The mathematical representations of the Piston-flow and Exponential models are given in equation 2.2 and 2.3 respectively.

$$g(t) = d\,(t\text{-}t) \qquad \text{Eq. (2.2)}$$

$$g(t) = 1/t \cdot \exp(-t/t) \qquad \text{Eq. (2.3)}$$

Where the main model parameter (t) is the mean residence time of the system (MRT)

The model performance is evaluated using the Nash-Sutcliffe efficiency measures (see equation 2.4) as described by Nash-Sutcliffe (1970). The value ranges from minus infinity to 1, where higher values indicate better agreement. A negative value of E_{NS} indicates that the observed mean is a better predictor than the model simulation.

Eq.(2.4)

Where, $\delta_{sim,}$ is the simulated output signature of streamflow, $\delta_{obs,i}$ is observed output streamflow signature, $\bar{\delta}_{obs,i}$ is the mean of observed output streamflow signature, and n is the obseravtion.

Results and Discussions

Characterization of isotope signal

The results of the precipitation isotopic composition depict both temporal and spatial pattern during the analysis period (see fig.3.1). Moreover, more depleted or more negative values are seen in the higher altitude (at Fana Choke 3393 m a.s.l) and more positive values are observed in the lower altitude.

The seasonal variation of the precipitation isotope composition shows distinct seasonality (see figure 3.2). During summer the values exhibit more negative and during spring and winter the values showed positive isotopic composition.

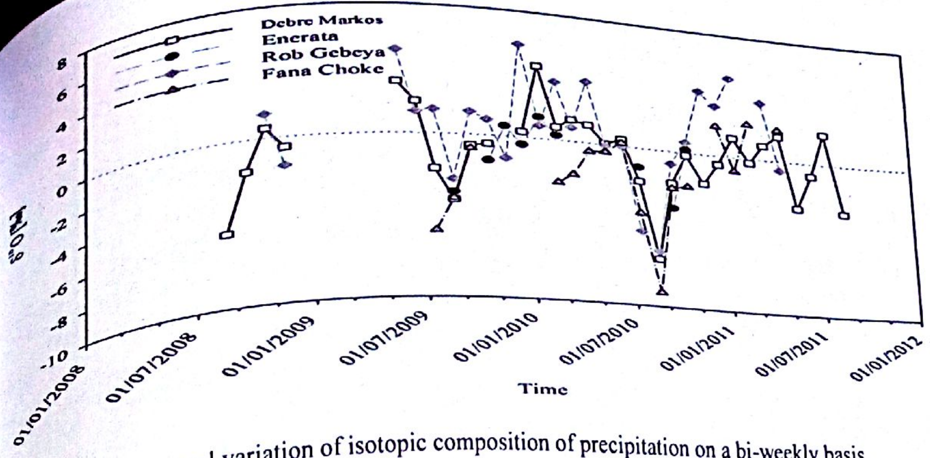


Fig. 3.1 Temporal variation of isotopic composition of precipitation on a bi-weekly basis.

These variations among seasons indicate the different moisture source generating rainfall in the study area. These results are in line with the findings in different parts of the globe that the isotope signal showed depletion at higher altitude and enrichment at the lower altitude (e.g. Gat, 1996; Levin et al., 2009).

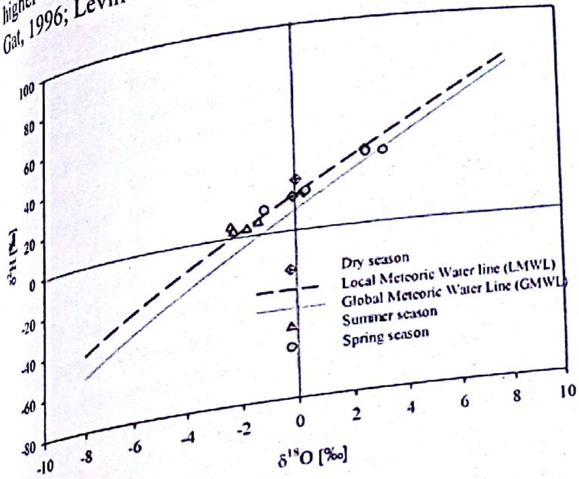


Figure 3.2 Relationship between, $\delta^{18}O$ and $\delta^{2}H$ depicting seasonal variation.

The temporal variations of streamflow signature indicate the contribution of streamflow during events is mainly from the new water. The mean volume weighted $\delta^{18}O$ isotope value for the Chemoga catchment was -1.4‰, and the $\delta^{2}H$ composition was 2.7‰. It is shown in figure 3.3 that during the main rainy season the isotope signature of streamflow did not exhibit considerable damping effect as compared to precipitation isotope signature. These results substantiate the dominant of event water contribution in this agriculturally dominated catchment (Tekleab et al. 2014).

Estimation of mean residence time

The result of the mean residence time using the exponential model at the outlet of Chemoga meso-scale catchment is found to be 3.5 months. As it is illustrated in (figure 3.4), the model predicted well reasonably the output streamflow signature as evaluated by the Nash and Sutcliffe model efficiency measure (E_{NS} = 0.72). Similarly the Piston-flow model estimated the mean residence time of approximately 3 months (see figure 3.5). Furthermore, the model predicted well the output streamflow signature as evaluated by the Nash and Sutcliffe efficiency model efficiency measure (E_{NS} = 0.69).

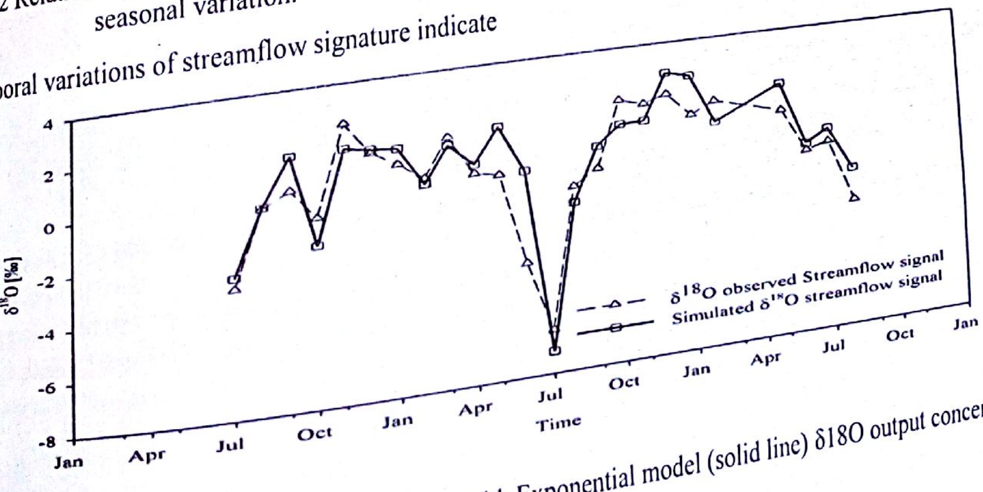


Figure 3.4 Observed (triangles) dashed line and fitted (square) with Exponential model (solid line) δ18O output concentrations at

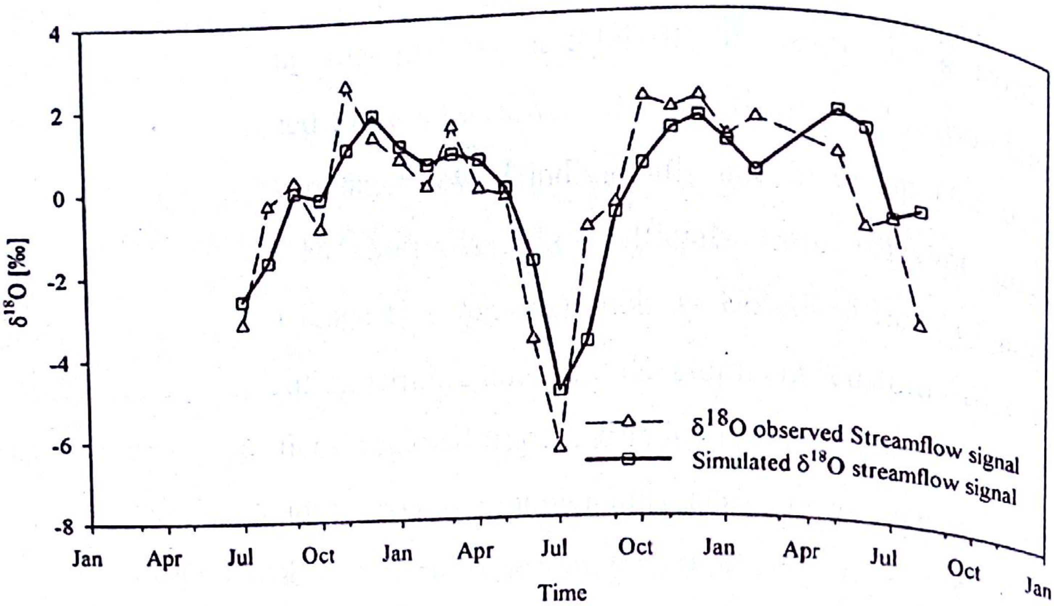


Figure 3.5 Observed (triangles) dashed line and fitted (square) with Piston flow model (solid line) δ18O output concentrations at catchment outlet (τ = ~3.0 months).

The results of the mean residence time based on these two lumped model are in agreement with the estimation of the mean residence time of water based on the periodic regression analysis to fit the seasonal sine wave models in the same catchment (Tekleab et., al 2014). In their study using sine wae regression approach the mean residence times was estimated as 4.1 months. Thus the mean residence times varies between 3- 4.1 months.

This suggests the roubustness of the methods in estimating approximately similar mean residence times. However, it is not always the case that agriculturally dominated catchments would have short mean residence times the results cannot generalized to be the same in different regions. As demonstrated by McGlynn et al. (2003), the mean residence time in a catchment varies depending on topography, soil types, land cover, and geologic properties. Consequently, irrespective of the catchment size the mean residence times might have short or long mean residence time. Hence, care has to be taken in estimating the mean residence time and travel time distribution by assuming time in variant climate inputs.

Conclusions

The present paper explores the use of stable environmental isotope data for the estimation of mean residence time in the Chemoga meso-scale catchment, Abay/Upper Blue Nile basin. The lumped parameter models are used to estimate the men residence times. The results of the analysis exhibit short mean residence times estimated by both models. The estimated results are plausible in a sense that during the period of analysis it has been observed that the river could not supply sustained base flow in the dry season. Moreover, the short mean residence time indicate the stream water generated in the river is from young age of shallow groundwater mainly contributed from the new water. It can be concluded that the method gives first approximation of the mean residence time with a lumped approach, the results could be improved by taking into account fine resolution sampling of events and estimation of time variable travel time distribution. In general, the results warrant catchment management aiming at increasing of soil water retention and recharge to enable sustainable development in this agriculturally dominated catchment.

References

Dunn, S.M., McDonnell, J.J., and Vache, K.B. Factors influencing the residence time of catchment waters: A virtual experiment approach, Water Resour. Res., 43, W06408, doi: 10.1029/2006WR005393, 2007.

Kebede, S., and Travi, Y. Origin of the $\delta^{18}O$ and $\delta^{2}H$ composition of meteoric waters in Ethiopia. Quaternary International, 257, 4-12, doi:10.1016/j.quaint.2011.09.032, 2012.

Gat, J. R., Bowser, C. J., and Kendall, C. The contribution of evaporation from the Great Lakes to the continental atmosphere: Estimate based on stable isotope data: Geophysical Research Letters, v.21, p.557-560, 1994.Gat, J.R.: Oxygen and Hydrogen isotopes in the hydrologic cycle, Annual Review Earth Planetary Sciences., 24, 225–262, 1996.

Hargreaves, G. H. and Samani, Z. A. Estimating potential evaporation, J. Irrig. Drain. E.-ASCE, 108, 225–230, 1982.

Hrachowitz, M., Soulsby C., Tetzlaff, D., Dawson, J.J.C., Dunn S.M, and Malcolm I.A.: Using longer-term data sets to understand transit times in contrasting headwater catchments, Journal of Hydrology, doi:10.1016/j.jhydrol.2009.01.001, 2009.

Hrachowitz, M., Soulsby, C., Tetzlaff, I., and Malccolm, A. Sensitivity of mean transit time estimates to model conditioning and data availability, Hydrol. Processes., 25, 980-990, 2011.

International Atomic Energy Agency.: IAEA-WMO Programme on Isotopic Composition of Precipitation: Global Network of Isotopes In Precipitation (GNIP) Technical procedure for sampling, 2009.

Levin, N.E., Zipser, E.J., and Cerling, T.E. Isotopic composition of waters from Ethiopia and Kenya: Insight into moisture sources for eastern Africa., Journal of Geophysical Research., Vol. 114, D23306, doi: 10.1029/2009JD012166, 2009.

Maloszewski, P. and Zuber, A. Determining the turnover time of groundwater systems with the aid of environmental tracers, Models and their applicability, J. Hydrol., 57, 207-231, 1982.

Maloszewski, P, and Zuber, A. Lumped parameter models for the interpretation of environmental tracer data. In: Mannual on Mathematical Models in Isotope Hydrology, 9-58. IAEA. TECDOC-910, International Atomic Energy Agency, Vienna, 1996.

McDonnell, J.J. A rational for old water discharge through macro pores in a steep humid catchment, Water Resour. Res., 26:2821-2832, 1990.

McDonnell, J.J., McGuire,K., Aggarwal, P., Beven, K.j., Biondi, D., Destouni, G., Dunn, S., James, A., Kirchner, J., Kraft, P., Lyon, S., Maloszewski, P., Newman, B., Pfister, L., Rinaldo, A., Rodhe, A., Sayama, T., Seibert, J., Solomon, K., Soulsby, C., Stewart,M., Tetzzlaff, D., Tobin, C., Troch, P., Weiler, M., Western, A., Worman, A., and Wrede, S. How old is streamwater? Open questions in catchment transit time conceptualization, modelling and analysis. *Hydrol. Process*. 24, 1745–1754, 2010.

McGlynn, B, McDonnell, J, Stewart, M, and Seibert, J. On the relationship between catchment scale and stream water mean residence time. Hydrological Processes, 17: 175–181, 2003.

McGuire, K.J., DeWalle, D.R., and Gburek, W.J. Evaluation of mean residence time in subsurface waters using oxygen-18 fluctuations during drought conditions in the semi-Appalachains, J. Hydrol., 261 (2002) 132-149, 2002.

McGuire, K.J. and McDonnell, J.J. A review and evaluation of catchment transit time modeling, J. Hydrol., 330, 543– 563, 2006.

Mul, M. L., Mutiibwa, K. R., Uhlenbrook, S, and Savenije, H.H.G. Hydrograph separation using hydro-chemical tracers in the Makanya catchment, Tanzania, Phys. Chem. Earth., 33, 151–156, 2008.

Munyaneza, O., Wenninger, J., and Uhlenbrook, S. Identification of runoff generation processes using hydrometric and tracer methods in a meso-scale catchment in Rwanda, Hydrol. Earth Syst. Sci., 16, 1991–2004, doi: 10.5194/hess-16-1991, 2012.

Nash, J. E. & Sutcliffe, J. V. River flow forecasting through conceptual models, Part I –A discussion of principles. J. Hydrol. 10, 282–290, 1970.

NMSA (National Meteorological service Agency). Climatic and agro-climatic resources of Ethiopia, NMSA Meteorological Research Report Series. V1, No. 1, Addis Ababa, 137p, 1996.

Rodgers, P, Soulsby, C., Waldron, S., and Tetzlaff, D. Using stable isotope tracers to access hydrological flow paths, residence times and landscape influences in a nested mesoscale catchment, Hydrol. Earth Syst. Sci., 9: 139–155, 2005.

Tekleab, S., Wenninger, J., and Uhlenbrook, S. Characterisation of stable isotopes to identify residence times and runoff components in two meso-scale catchments, Abay/Upper Blue Nile basin, Ethiopia. Hydrol. Earth Syst. Sci., 18, 2415–2431, doi: 10.5194/hess-18-2415, 2014.

Wissmeier, L. and Uhlenbrook, S. Distributed, high-resolution modeling of ^{18}O Signals in a meso-scale catchment. Journal of Hydrology, 332, 497–510, doi:10.1016/j.jhydrol.2006.08.003, 2007.

ANALYSIS OF CLIMATE CHANGE IMPACTS ON THE FLOWS AND WATER RESOURCES OF UPPER BLUE NILE RIVER USING SWAT.

Solomon S. Ewnetu [1], Prof. W. Bauwens [2], Prof. A. Van Griensven[3], Tadesse A. Abitew [4]

[1] *Lecturer, School of Natural Resource and Environmental Engineering, Haramaya University, P.O.Box 79, Harar, Ethiopia (Email: soloseb@yahoo.com)*

[2] *Professor, Faculty of Engineering, Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel (VUB), Brussels, Belgium. (Email: wbauwens@vub.ac.be)*

[3] *Professor, Faculty of Engineering, Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel (VUB), Brussels, Belgium. (Email: avgriens@vub.ac.be)*

[4] *PhD Student, Faculty of Engineering, Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel (VUB), Brussels, Belgium. (Email: tade.alex@vub.ac.be)*

Abstract:

The aim of this study was to assess the impacts of climate change on flows and water resources of the Upper Blue Nile River using the Soil and Water Assessment Tool (SWAT). The SWAT model was calibrated using a combination of manual and automatic calibration techniques in monthly time scale at three gauging stations (i.e. Bahir Dar, Kessie and Border). The evaluation the SWAT model for calibration periods was very good; with NSE values of 0.82, 0.88 and 0.81 at Bahir Dar, Kessie and Border, respectively. However, the prediction capacity of the SWAT model reduced during validation period, with NSE values of 0.53, 0.65 and 0.77 at Bahir Dar, Kessie and Border, respectively. Considering graphical and statistical performance criteria, The SWAT model performed well. Then, the SWAT model can be used for future climate change scenario investigation. To investigate the climate change impacts steps are; (1) The SWAT model was built up for Upper Blue Nile Basin, (2) The SWAT model was calibrated and validated for the periods of eleven years 1975 to 1985 and ten years 1986 to 1995, respectively. (3) Finally, The SWAT model was used to simulate the baseline periods and future climate change scenarios. The impacts of future climate change on water yield, precipitation, evapotranspiration and potential evapotranspiration were then investigated using one GCM time series under RCP 4.5 and RCP 8.5 scenarios for the two future periods 2050's (2035–2065) and 2080's (2065–2095). The comparisons were done between baseline periods (1970 – 2000) and the two future window periods. The results reveals that (a) the annual precipitation in most part of the Upper Blue Nile River Basin will likely increase for the two scenarios and the two periods (b) corresponding to increase in precipitation, the water yield in most part of the basin will likely increase in both scenarios for the two window periods except the water yield under RCP 4.5 for the periods of 2050's is projected to decrease. (c) The annual evapotranspiration will probably increase in all scenarios. (d) The average stream flows at the outlet of the basin will likely experience a significant increase under the two scenarios for the periods of 2050's and 2080's. It is predicted that the increase trend higher during the periods of 2080's as compared to 2050's. Generally, considering the continuous change of climate, the Upper Blue Nile Basin water resources will probably improve. Nevertheless, to have a better understanding of future impacts, the model need to be calibrated on daily scale and using several GCM time series with different scenarios to have a wide range of prediction.

Keywords: Climate change, Impacts, SWAT model, Blue Nile

Introduction

Nowadays climate change impacts associated with global warming as a result of an increase in greenhouse gases (GHG) has been a big issue that has given attention worldwide. There are a number of studies that show the impact of climate change on the Nile River flow (Taye et al., 2011; Yates and Strzepek, 1998; Beyene et al., 2010; Kim and Kaluarachchi, 2009; Koch and Cherie, 2013; Mengistu and Sorteberg, 2012).

The Nile River basin water resources have already been under massive pressure due to various competitive uses as well as social, political and legislative situations. Furthermore, previous studies reveals that many parts of the Nile basin are sensitive to climatic variations (Conway and Hulme, 1996;

Yates and Strzepek 1996, 1998a, b; Conway, 2005; Kim and Kaluarachchi, 2009; Beyene et al., 2010) indicating that climate change will have a considerable impact on the water resources. Therefore, studying the possible change in the water resources due to the continuous change in climate has paramount importance for water resource management and informed decision making. This study tried to quantify the possible impacts of climate change on hydrology and water resources of the Upper Blue Nile River Basin. It will assume the land use and physical properties of the catchment remained constants. These are important assumptions which might have considerable effect on the hydrology of the system.

Study Area

The upper Blue Nile is the major tributary of the Nile and is located within the western and central part of Ethiopian between latitudes 7° 45' and 12° 45'N and longitudes 34° 05' to 39°45'E. The Upper Blue Nile River Basin is major part of the Abay basin with a drainage area of 172 300 km2. The river originates in Ethiopian highlands specifically is called locally Gilligel Abay (meaning little river) which feed the Lake Tana and flows to the Sudanese Border to eventually meet the White Nile River at Khartoum, Sudan. The altitude of the basin ranges from 485 m to 4257 m. Figure 4.1 shows the physical layout of the basin and its tributaries have a general slope towards the Sudan border; however the slopes are steeper in the east than in the west and northeast areas of the study area.

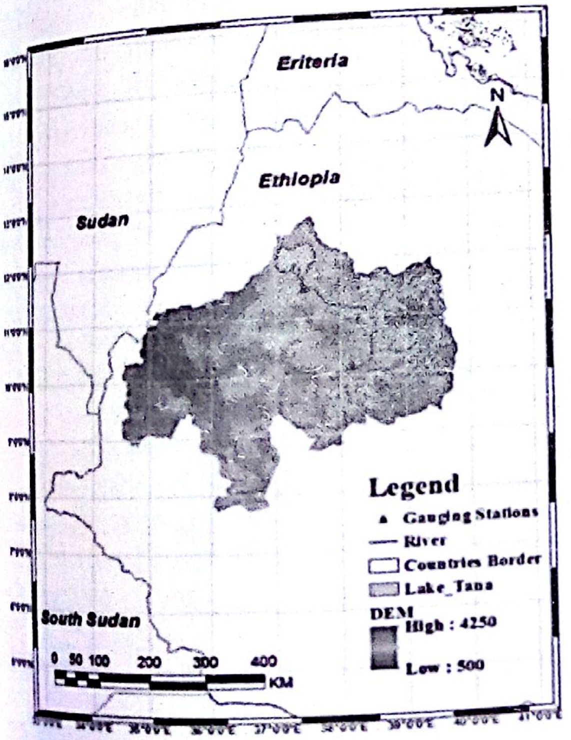


Figure 4.1 Physical layout of the Upper Blue Nile River Basin

Data Collection and SWAT input preparation

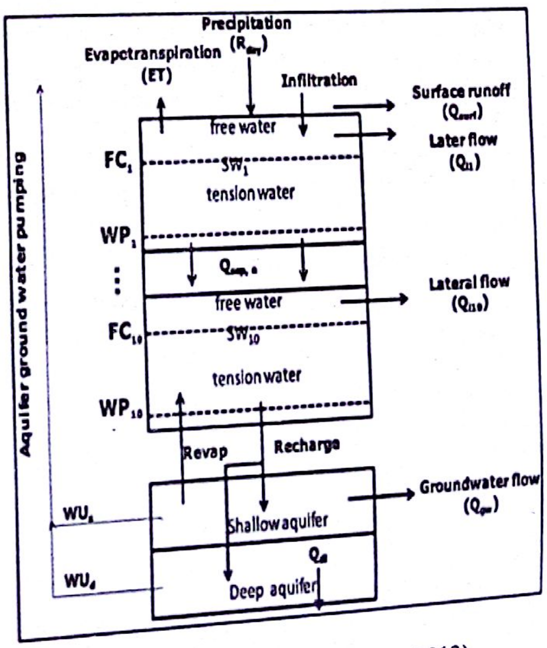
Input material/data used to develop a SWAT hydrological model for Upper Blue Nile river basin, can be classified into four major classes as follows;

- Spatial information consists of Digital Elevation Model (DEM), land use map and soil map
- Hydro-meteorological information comprised of time series of flow measurements at three stations, rainfall, temperature, wind speed, solar radiation and relative humidity
- SWAT database files
- Lake/reservoirs input parameters

Description of Soil and Water Assessment Tool (SWAT)

The Soil and Water Assessment Tool or its acronym SWAT, it is a river basin or watershed scale model. It is physical-based, semi-distributed, continuous time (not designed to simulate detailed single flood event) hydrologic simulator for river basins or watersheds. SWAT operates on a daily or sub-daily time base, at river basin scale. In SWAT, a basin is divided into multiple sub-basins, which are then further subdivided into hydrologic response units (HRUs) that consist of homogeneous land use, management, topographical, and soil characteristics. The water balance in SWAT is the driving force behind flow components in the watershed. Simulation of the hydrology of a watershed can be separated into two major divisions.

Figure 4.1 The schematic representation of hydrological



components in SWAT (Leta, 2013)

Performance evaluation of calibration and validation results

The Hydrological SWAT model calibration and validation was evaluated through multi-objective criteria's at each station in the basin. The performance indicators used includes annual water balance, statistical indices, and graphical goodness-of-fit as discussed in the following sections.

Statistical indices of model evaluation

The goodness-of-fit and the degree to which the calibrated and validated model accounts for uncertainty are evaluated using Nash-Sutcliffe Efficiency (NSE), coefficient of determination (R^2) and percentage bias (PBIAS). The statistical evaluations of the model for all stations are stated in the Table 5.5.

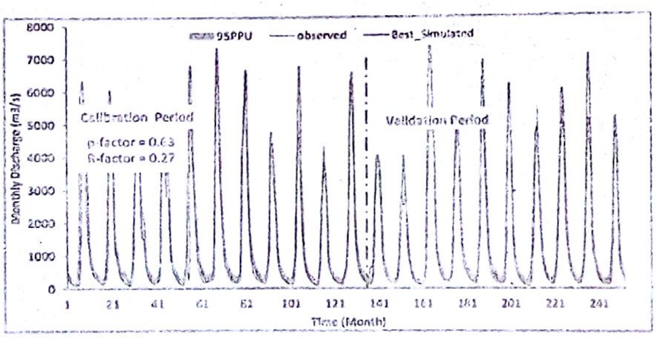
Table 5.5 Monthly Statistical Evaluation of SWAT-model performance for calibration- and validation period at three stations.

Graphical Evaluation

Station Name	Calibration Period				Validation Period			
	R^2	NSE	PBIAS (%)	RSR	R^2	NSE	PBIAS (%)	RSR
Bahir Dar	0.82	0.82	-3.6	0.43	0.55	0.53	7.4	0.69
Kessie	0.88	0.88	0.9	0.35	0.65	0.65	-5.6	0.59
Border	0.83	0.81	5.3	0.43	0.77	0.76	0.4	0.49

The graphical techniques provide a visual comparison goodness- of- fit between observed and simulated hydrograph used to judge the quality of the model with respect hydrograph shape, low flow and peak flows. The graphical comparison plots on a monthly scale of calibration and validation period of the tested measurement at border stations is illustrated in Figure 5.9.

Figure 5.9 Time series of observed and simulated monthly



stream flow with 95 % prediction uncertainty (95PPU) during the calibration (left) and validation (right) period at Border station

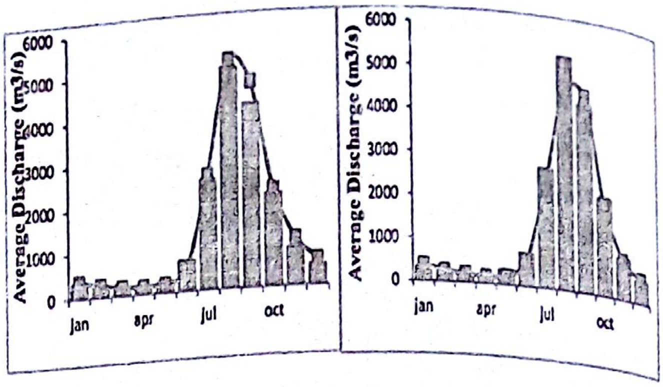


Figure 5.10 Seasonal variation simulated versus observed river flow during calibration period (left) and validation period (right) at three respective stations.

Hydrological water balance

Water balance is the main driving force behind flow components in the watershed. It comprises of different component of input, output and change in storage. So studying and checking the global water balance helps to compare the output of a model to input on annual scale and to understand the magnitude of order of various hydrological processes in the basin. Table 5.7 summarized the annual details of various hydrological processes at basin scale for the total time period (1975-1995), the calibration period (1975 -1989) and the validation period (1990-1995).

Table 5.7 Upper Blue Nile river basin global annual water balance components for total time series periods, calibration and validation periods at the basin level.

	Total Time series (mm/year)	Calibration Period (mm/year)	Validation Period (mm/year)
Precipitation	1346	1361	1329
Surface Runoff Q	233	243	222
Lateral Soil Q	20	21	20
Ground Water (SHAL AQ) Q	91	90	92
REVAP (SHALAQ SOIL/PLANTS)	77	77	77
Deep AQ Recharge	19	19	18
Total AQ Recharge	190	190	189
Total Water YLD	344	352	335
Percolation OUT OF SOIL	187	190	184
ET	904	906	901
PET	1651	1660	1642

Climate Change Scenario Selection

In this study the result of two GCMs time series and two scenarios for the Upper Blue Nile Basin are obtained from Department of Urban & River Hydrology and Hydraulics, Katholieke Universiteit Leuven. These future data series includes daily precipitation, daily minimum and maximum temperature for the year 2020 -2100.

Table 6.1 Description of CMIP5 GCMs Model

Model Name	Country	Long.	Lat.	Resolution
MIROC5	Japan	1.40	1.40	High
BCC-CSM1.1m	China	1.12	1.12	High

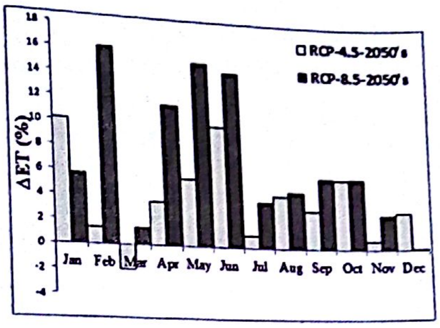
For this study, based on The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) two scenarios were selected. These scenarios can be explained as follows,

Representative concentration pathway (RCP 8.5) is characterized by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high greenhouse gas concentration levels (Riahi et al., 2011).

Whereas, RCP 4.5 is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level (Thomson et al., 2011).

Impact of Climate Change on Evapotranspiration

The actual evapotranspiration (ET) is calculated from the daily precipitation, maximum and minimum temperature data, and synthetic data on solar radiation, wind speed and relative humidity generated by the SWAT weather generator. The concentration of CO_2 from swat subbasin file was edited according to the future climate scenario since the increase in concentration of CO_2 in the future may enhance transpiration on the plant leaf. As shown in the Figure 5.16, In the Upper Blue Nile Basin, the evapotranspiration will likely tend to increase during most of the month of the two periods 2050's and 2080's. The annual actual evapotranspiration is predicted to increase 4% (-2% to 6%) using RCP 4.5 and 7% (0 to 16%) using RCP 8.5 in the periods of 2050's, to increase 6 % (-8% to 21%) using RCP 4.5 and 10% (-14 to +16) using RCP 8.5 in the periods of 2080's.



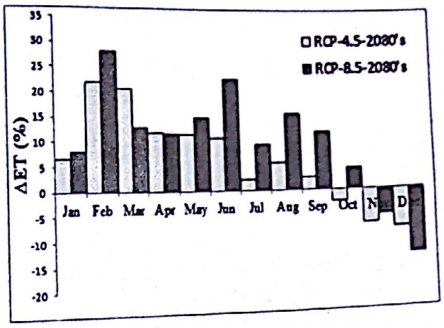
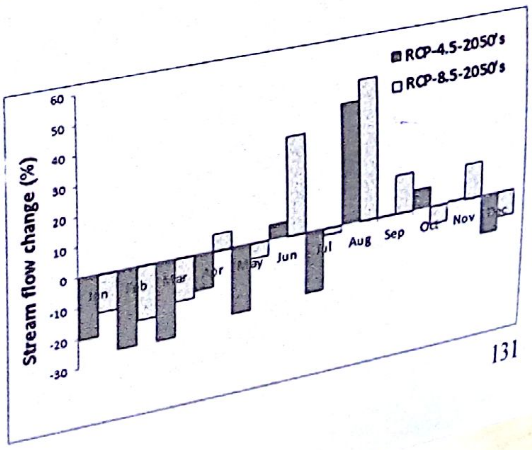


Figure 5.16 Relative changes of average monthly Evapotranspiration near Sudan Border in the periods 2050's (2035 to 2065) and 2080's (2065 to 2095)

6.2 Impact of climate change in Stream Flow

Figure 5.17 shows the relative changes in the monthly stream flow of the Blue Nile River at the basin outlet near Sudan Border predicted by SWAT according to one GCM model result for the two scenarios and two window periods. As shown Figure 5.17, in the periods of 2050's, both scenarios, the largest decrease in stream flow are predicted during the dry season from December to April. This decreasing trend of low flow may correspond to the relative increment of actual evapotranspiration during dry season. However, the increase in stream flow is predicted in August in which historically most of peak flow values have been observed in this month.

Overall in the periods of 2050's, for scenario RCP 4.5, the average annual stream flow is predicted to decrease in average (range) – 6 % (-25% to +41). But according to scenario RCP 8.5, the average annual stream flow is predicted to increase in average (range) +4% (-25% to +50).



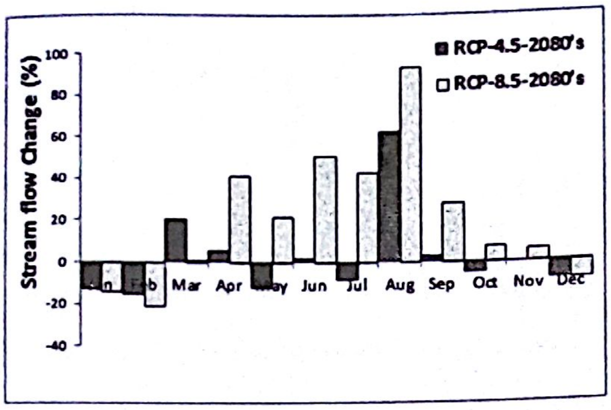


Figure 5.17 Relative changes of average monthly stream flow near Sudan Border in the periods 2050's (2035 to 2065) and 2080's (2065 to 2095)

The average changes of climate variables at subbasins level

The percentage difference is calculated based on the average of data periods 2035 -2065 and 2065 -2085 from the average of baseline period 1970 – 2000. This provides general pictures of climate change impacts on water balance components at sub-basins level.

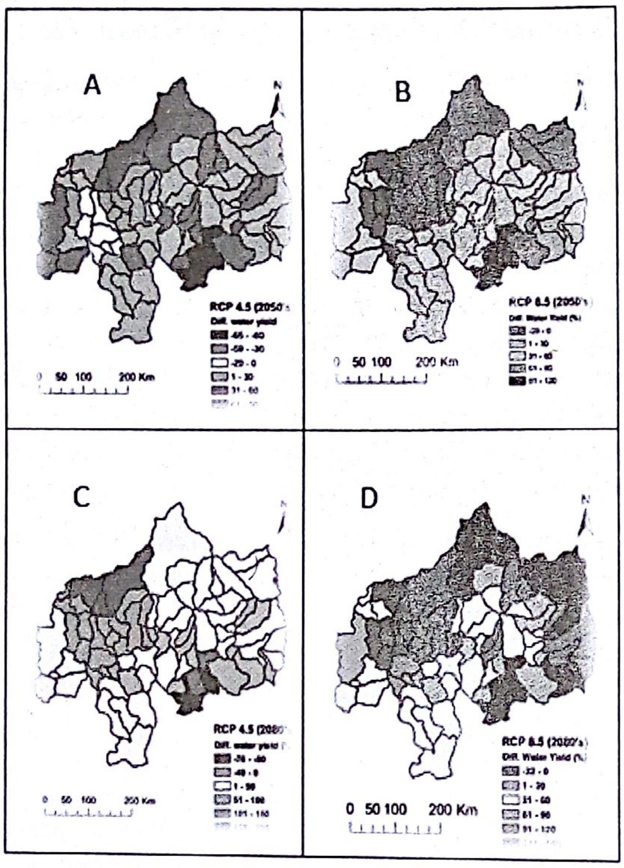


Figure 5.24 Relative changes in average water yield at Subbasin Level for 2050's periods (A and B) and for the period 2080's (C and D) at subbasin level, where A and C represents RCP 4.5 and B and D represent RCP 8.5.

As shown in the Figure 5.24, there will be higher spatial variability of climate change impacts on the water yield within the basin. It is observed that water yield will probably increase eastern parts of the basins. However, north western parts of the basin shows decreasing trend. It is observed that the water yield in the basin will be very sensitive compared to hydrological components, the percentage change in water yield ranges -75 % to + 200 % at sub-basin level.

Conclusion and Recommendations

To make sure the SWAT model is a good representation of the basin, The model was calibrated and validated using combination of manual and automatic calibration techniques in monthly time scale at three gauging stations (i.e. Bahir Dar, Kessie and Border). The evaluation the SWAT model for calibration periods was very good; with NSE value of 0.82, 0.88 and 0.81 at Bahir Dar, Kessie and Border, respectively. The annual water yield simulated and measured flows are compared at each of all three gauging stations during the calibrated and validated period. The model results for all stations gives good much of annual water yield between simulated and measured with less than 10% discrepancy. Overall performance evaluation suggests that the model can be used for Climate scenario investigation.

The climate change impacts scenarios were implemented to calibrated and validated SWAT model using one GCMs time series is known as BCC-CSM1.1m and under two scenarios RCP 4.5 and RCP 8.5. The SWAT model forced to simulate the future time series (precipitation, maximum and minimum temperature) of BCC-CSM1.1m for the two scenarios during the periods of 2050's (2035 to 2065) and 2080's (2065 to 2095). The analysis of climate change impacts has been done looking at the magnitude of relative change in climate variables during periods of 2050's (2035 to 2065) and 2080's (2065 to 2095) from the baseline periods (1970 to 2000) at basin and subbasins level.

The analysis of climate change impacts can be summarized into following points;

Future predictions indicate that the annual precipitation will likely tend to increase in most part of the basin for the two simulation periods. However, using RCP 4.5, the precipitation is predicted to decrease in the periods (2035 to 2065)

The annual water yield will probably increase in the basin during two periods of simulations correspond to the increase in annual precipitation. However, Using RCP 4.5, the water yield will likely to decrease in the periods (2035 to 2065).

The actual evapotranspiration will tend to increase in all scenarios.

In general, the study reveals that the water resources of the Upper Blue Nile basin will probably improve in the future considering the change in precipitation and maximum and minimum temperature using one GCM time series. This study could provide useful insight on the water availability and probable impacts of climate change for water management and policy makers.

This study attempted to look at the trends of climate changes impacts on hydrology and the water resources of the Upper Blue Nile basin using one GCM time series and two Scenarios. In order to improve further the study, the following recommendations are made;

Though the SWAT model performed well for predicting monthly stream flows, further calibration of the SWAT model using daily stream flows is recommended.

In order to have a wide range of climate change impacts using several GCMs model time series and different scenarios is advised.

Evaluation of WATCH weather datasets should have to be done using more than two stations.

It is highly recommended to collect of sufficient hydro-meteorological data for the study.

It would be interesting that the study supported by evidence of socioeconomic change such as the rapid increase in population in Ethiopia may have negative

impacts to the water availability of the study area.

This study considered the land use/cover and others soil parameters are unchanged. In order to have a wider range of climate change impacts scenarios, further studies are suggested on analysis of climate change impacts under changing in land use/cover.

Acknowledgements:

The leading author of this paper would like to thank the Vlaamse Interuniversitaire Raad (VLIR), Belgium for providing MSc scholarship to carry out this research.

References

Abbaspour, K.C., 2009. SWAT-CUP2. SWAT Calibration Uncertain. Programs Version 2.

Abbaspour, K.C., Faramarzi, M., Ghasemi, S.S., Yang, H., 2009. Assessing the impact of climate change on water resources in Iran. Water Resour. Res. 45.

Abbaspour, K.C., Vejdani, M., Haghighat, S., 2007. SWAT-CUP calibration and uncertainty programs for SWAT, in: MODSIM 2007 International Congress on Modelling and Simulation, Modelling and Simulation Society of Australia and New Zealand.

Arnold, J.G., Kiniry, J.R., Srinivasan, R., Williams, J.R., Haney, E.B., Neitsch, S.L., 2011. Soil and Water Assessment Tool input/output file documentation, version 2009. US Dep. Agric.-Agric. Res. Serv. Grassl. Soil Water Res. Lab. Temple TX Blackland Res. Ext. Cent. Tex. AgriLife Res. Temple TX Tex. Water Resour. Inst. Tech. Rep.

Arnold, J.G., Moriasi, D.N., Gassman, P.W., Abbaspour, K.C., White, M.J., Srinivasan, R., Santhi, C., Harmel, R.D., Van Griensven, A., Van Liew, M.W., 2012. SWAT: Model use, calibration, and validation. Trans. ASABE 55, 1491–1508.

Arnold, J.G., Srinivasan, R., Muttiah, R.S., Williams, J.R., 1998. Large area hydrologic modeling and assessment part I: Model development1. Wiley Online Library.

Betrie, G.D., Mohamed, Y.A., Griensven, A. van, Srinivasan, R., 2011. Sediment management modelling in the Blue Nile Basin using SWAT model. Hydrol. Earth Syst. Sci. 15, 807–818.

Beyene, T., Lettenmaier, D.P., Kabat, P., 2010. Hydrologic impacts of climate change on the Nile River Basin: implications of the 2007 IPCC scenarios. Clim. Change 100, 433–461.

Box, G.E., Cox, D.R., 1964. An analysis of transformations. J. R. Stat. Soc. Ser. B Methodol. 211–252.

Change, I.P.O.C., 2001. Climate change 2007: impacts, adaptation and vulnerability. Genebra Suíça.

Conway, D., 1997. A water balance model of the Upper Blue Nile in Ethiopia. Hydrol. Sci. J. 42, 265–286.

Conway, D., 2000. The climate and hydrology of the Upper Blue Nile River. Geogr. J. 166, 49–62.

Conway, D., 2005. From headwater tributaries to international river: observing and adapting to climate variability and change in the Nile basin. Glob. Environ. Change 15, 99–114.

Dibike, Y.B., Coulibaly, P., 2005. Hydrologic impact of climate change in the Saguenay watershed: comparison of downscaling methods and hydrologic models. J. Hydrol. 307, 145–163.

Douglas-Mankin, K.R., Srinivasan, R., Arnold, J.G., 2010. Soil and Water Assessment Tool (SWAT) model:

Current developments and applications. Trans ASABE 53, 1423–1431.

Easton, Z.M., Fuka, D.R., White, E.D., Collick, A.S., Biruk Asharge, B., McCartney, M., Awulachew, S.B., Ahmed, A.A., Steenhuis, T.S., 2010. A multi basin SWAT model analysis of runoff and sedimentation in the Blue Nile, Ethiopia. Hydrol. Earth Syst. Sci. Discuss. 7, 3837–3878.

Gassman, P.W., Reyes, M.R., Green, C.H., Arnold, J.G., 2007. The soil and water assessment tool: historical development, applications, and future research directions. Center for Agricultural and Rural Development, Iowa State University.

Griensven, A. van, Ndomba, P., Yalew, S., Kilonzo, F., 2012. Critical review of the pplication of SWAT in the upper Nile Basin countries. Hydrol. Earth Syst. Sci. Discuss. 9, 3761–3788.

Johnson, P.A., Curtis, P.D., 1994. Water balance of Blue Nile river basin in Ethiopia. J. Irrig. Drain. Eng. 120, 573–590.

Kim, U., Kaluarachchi, J.J., 2009. Climate Change Impacts on Water Resources in the Upper Blue Nile River Basin, Ethiopia1. JAWRA J. Am. Water Resour. Assoc. 45, 1361–1378.

Kim, U., Kaluarachchi, J.J., Smakhtin, V.U., 2008. Climate change impacts on hydrology and water resources of the Upper Blue Nile River Basin, Ethiopia. Download full text free.

Koch, M., Cherie, N., 2013. SWAT Modeling of the impact of future climate change on the hydrology and the water resources in the upper Blue Nile river basin, Ethiopia, in: Proceedings of the 6th International Conference on Water Resources and Environment Research, ICWRER. pp. 3–7.

Leta O.T 2013. Catchment Processes Modeling, Including the Assessment of Different Sources of Uncertainty, Using the SWAT Model: the River Zenne Basin (Belgium) Case Study, PhD dissertation Thesis, Vrije Universiteit Brussel (VUB), Brussels

Leta, O.T., Shrestha, N.K., de Fraine, B., van Griensven, A., Bauwens, W., 2014. Integrated Water Quality Modelling of the River Zenne (Belgium) Using OpenMI, in: Advances in Hydroinformatics. Springer, pp. 259–274.

Ma, L., Ascough, J.C., Ahuja, L.R., Shaffer, M.J., Hanson, J.D., Rojas, K.W., 2000. Root zone water quality model sensitivity analysis using Monte Carlo simulation. Trans. ASAE 43, 883–895.

Meinshausen, M., Smith, S.J., Calvin, K., Daniel, J.S., Kainuma, M.L.T., Lamarque, J.F., Matsumoto, K., Montzka, S.A., Raper, S.C.B., Riahi, K., 2011. The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. Clim. Change 109, 213–241.

engistu, D.T., Sorteberg, A., 2012. Sensitivity of SWAT simulated streamflow to climatic changes within the Eastern Nile River basin. Hydrol. Earth Syst. Sci. 16, 391–407.

Moriasi, D.N., Arnold, J.G., Van Liew, M.W., Bingner, R.L., Harmel, R.D., Veith, T.L., 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Trans ASABE 50, 885–900.

Neitsch, S.L., Arnold, J.G., Kiniry, J.R., Srinivasan, R., Williams, J.R., 2010. Soil and water assessment tool input/output file documentation version 2009. Tex. Water Resour. Inst. Tech. Rep. 365.

Raes, D., Steduto, P., Hsiao, T.C., Fereres, E., 2009. AquaCrop The FAO Crop Model to Simulate Yield Response to Water: II. Main Algorithms and Software Description. Agron. J. 101, 438–447.

Refshaard, J.C., Storm, B., Singh, V.P., 1995. MIKE SHE. Comput. Models Watershed Hydrol. 809–846.

Riahi, K., Krey, V., Rao, S., Chirkov, V., Fischer, G., Kolp, P., Kindermann, G., Nakicenovic, N., Rafai, P., 2011. RCP-8.5: exploring the consequence of high emission trajectories. Clim. Change Doi 10, 1007.

Seleshi, Y., Zanke, U., 2004. Recent changes in rainfall and rainy days in Ethiopia. Int. J. Climatol. 24, 973–983.

Setegn, S.G., Srinivasan, R., Dargahi, B., 2008. Hydrological modelling in the Lake Tana Basin, Ethiopia using SWAT model. Open Hydrol. J. 2, 49–62.

Sutcliffe, J.V., Parks, Y.P., 1999. The hydrology of the Nile. International Association of Hydrological Sciences Wallingford, Oxfordshire, UK.

Taye, M.T., Ntegeka, V., Ogiramoi, N.P., Willems, P., 2011. Assessment of climate change impact on hydrological extremes in two source regions of the Nile River Basin. Hydrol. Earth Syst. Sci. 15, 209–222.

Tekleab, S., Uhlenbrook, S., Mohamed, Y., Savenije, H.H.G., Temesgen, M., Wenninger, J., 2011. Water balance modeling of Upper Blue Nile catchments using a top-down approach. Hydrol. Earth Syst. Sci. 15, 2179–2193.

Thomson, A.M., Calvin, K.V., Smith, S.J., Kyle, G.P., Volke, A., Patel, P., Delgado-Arias, S., Bond-Lamberty, B., Wise, M.A., Clarke, L.E., 2011. RCP4. 5: a pathway for stabilization of radiative forcing by 2100. Clim. Change 109, 77–94.

Ullrich, A., Volk, M., 2009. Application of the Soil and Water Assessment Tool (SWAT) to predict the impact of alternative management practices on water quality and quantity. Agric. Water Manag. 96, 1207–1217.

Waterbury, J., 1979. Hydropolitics of the Nile valley. Syracuse University Press Syracuse, NY.

Weedon, G.P., Gomes, S., Viterbo, P., Shuttleworth, W.J., Blyth, E., Österle, H., Adam, J.C., Bellouin, N., Boucher, O., Best, M., 2011. Creation of the WATCH forcing data and its use to assess global and regional reference crop evaporation over land during the twentieth century. J. Hydrometeorol. 12, 823–848.

White, M.J., Harmel, R.D., Arnold, J.G., Williams, J.R., 2014. SWAT check: A screening tool to assist users in the identification of potential model application problems. J. Environ. Qual. 43, 208–214.

Whittington, D., Wu, X., Sadoff, C., 2005. Water resources management in the Nile basin: the economic value of cooperation. Water Policy 7, 227–252.

Willems, P., 2011. VHM approach: transparent, step-wise and data mining based identification and calibration of parsimonious lumped conceptual rainfall-runoff models. J Hydrol Revis.

Willems, P., 2012. Model uncertainty analysis by variance decomposition. Phys. Chem. Earth Parts ABC 42, 21–30.

Willmott, C.J., 1981. On the validation of models. Phys. Geogr. 2, 184–194.

WMO, 2008. Guide to Hydrological Practices. Volume I: Hydrology – From Measurement to Hydrological Information. WMO No. 168. 6th ed. World Meteorological Organisation, Geneva, Switzerland. ISBN 978-92-63-10168-6.

WMO, 2009. Guide to Hydrological Practices. Volume II: Management of Water Resources and Application of Hydrological Practices. WMO No. 168. 6th ed. World Meteorological Organisation, Geneva, Switzerland. ISBN 978-92-63-10168-6.

Xu, C., Widén, E., Halldin, S., 2005. Modelling hydrological consequences of climate change—progress and challenges. Adv. Atmospheric Sci. 22, 789–797.

Yates, D.N., Strzepek, K.M., 1998. Modeling the Nile basin under climatic change. J. Hydrol. Eng. 3, 98–108.

CHAMO LAKE WATER BALNACE RESPONSE TO CLIMATE CHANGE

Tariku Tesfaye Chomba

Department of Meteorology & Hydrology, Natural Science College, Arbaminch University

ABSTRACT

At present the sign of climate change and its impact is revealed in all spheres of different natural and manmade systems, in one way or the other. Particularly, this impact has become significant on the water resource systems as they are fragile in nature. One of the most important potential concerns of climate change effects is on the water balance studies of rift valley lakes of Ethiopia. Thus the main aim of the present study is to assess and analyze the Chamo Lake water balance response to climate change in Ethiopia. Projections of the future climatic conditions are made by using General Circulation Model (GCM). Using Statistical Down Scaling Method (SDSM), the climate variables at catchment level were downscaled. A hydrological model (HBV) was utilized to simulate the water balance. The performance of the model was assessed through calibration and validation processes that resulted as R^2=0.81 and R^2=0.85 respectively. The projected climate variables show an increasing trend for maximum temperature, minimum temperature and rainfall in the next century. The average annual minimum temperature is going to be increased by 1.6°C and 1.8°C for A2 and B2 scenarios respectively towards the end of this century. The maximum temperature is also going to increase by 2.2°C and 2.6°C for A2 and B2 scenarios respectively for the same time period. The projected precipitation reveals an annual increasing trend in all the three time horizons (i.e. 2020s, 2050s and 2080s) for both A2a and B2a emission scenarios. The evaporation from the Chamo open water generally shows an increasing trend for both the scenarios i.e. it exhibits an average annual increase of 14 % for A2a and 15.7% for B2a emission scenarios at the end of the next century. By using the projected basic water balance components, the future water balance of Chamo Lake was evaluated and the result shows a declining trend of Chamo Lake water storage in the entire three future time horizons.

Key Words: Climate Change, Lake Chamo, SDSM, Water Balance.

INTRODUCTION

Background

Today the environmental issue becomes the biggest concern of the mankind as a consequence of scientific evidence about the increasing concentration of greenhouse gases in the atmosphere and the changing climate of the Earth. Globally, the temperature is increasing and the amount and distribution of rainfall is being altered (Cubash, 2001).According to the international panel on climate change (IPCC, 2007) Scientific Assessment Report, global average temperature would rise between 1.4 and 5.8°C by 2100 with doubling of the CO_2 concentration in the atmosphere. Sea level rise, change in precipitation pattern (up to ±20%), and change in other local climate conditions are expected to occur as consequence of rising global temperature. This is expected to have a potential impact on different socio-economic sectors

The levels and sizes of lakes are governed by many natural and anthropogenic factors. Climatic, hydrological and man induced factors control lake levels in many ways. Changes in lake levels result from a shift in the water balance or the net steady-state removal of water via various surface and subsurface processes. In particular, closed terminal lakes fluctuate significantly in response to climatic changes but tend to maintain equilibrium between input and output (Tenalem,2002).

The Ethiopian rift is characterized by a chain of lakes of various sizes and hydrological and hydro-geological settings. The levels of some of these lakes have changed dramatically over the last three decades. Lakes that are relatively not influenced by human activities (Langano and Abaya) remain stable except for the usual inter annual variations, strongly influenced by rainfall. Some lakes have shrunk due to excessive utilization of water (such as Abiyata); others have expanded due to increases in surface runoff and groundwater flux from percolated irrigation water such as Beseka (Tenalem, 2009).

The Lake Chamo shows continuous change in the last few decades, the change in the lake level of Lake Chamo for the last 45 years is found to be significant. The lake has shrunk by 14.42% (50.12 km^2) with reference to the lake surface area of 1965. The Lake area earlier covered by water is now covered by Grazing ground, farm land and site to dig special type of clay used for salt lick (Alemayhu and Raju, 2011). Therefore having enough understanding of the lake water balance using different climatological and hydrological model is important. For that reason, this study mainly deals with Chamo Lake water balance response to climate change.

Objective of the study

The general objective of this study is to evaluate the Chamo Lake water balance response to climate changes under changing climate scenario. **Objective of the study**

The general objective of this study is to evaluate the Chamo Lake water balance response to climate changes under changing climate scenario.

Specific objectives

In order to achieve the main objective of the study, the following specific objectives are set as major indicators of the study

- To identify possible changes of Lake Chamo water balance due to climate change in the 21st century
- To assess and analyze land use and land cover changes in of the watershed
- To project and assess future changes of the climate (maximum temperature ,minimum temperature and precipitation)in the study area

Significance of the study

Kulfo_Sile watershed has a great economic importance for Arba Minch and Arba Minch Zuriya woreda. Arba Minch state farm which has 1200 hectare farm land and Sile private farm land which has 800 hectare uses Kulfo and Sile rivers for irrigation purpose consecutively .Kulfo and Sile rivers are the tributaries to Lake Chamo during the dry seasons there is no inflow to Lake Chamo from Kulfo and Sile rivers this is because of total diversion of rivers for irrigation purpose by farmers near the rivers, Arba Minch and Sile state farms respectively. Therefore the over utilization and miss use of Kulfo and Sile rivers in addition to climate change puts Lake Chamo under great danger now a days. The significance of this study is to assess and evaluate the magnitude of changes of Lake Chamo due to climate change and human induced factors, and assist decision makers, practitioners, program planners to develop strategies on proper utilization of lake chamo tributaries and rehabilitation of the declining lake chamo.

Material and methods

Description of the Study area

Lake Chamo located between 5°58.5′ and 6°35′ North latitude and 37°39′and 38°02′ East longitude. This Lake is located within the Main Ethiopian Rift Valley, Which extends from the Southern Afar to the Konso highlands in southern Ethiopia.

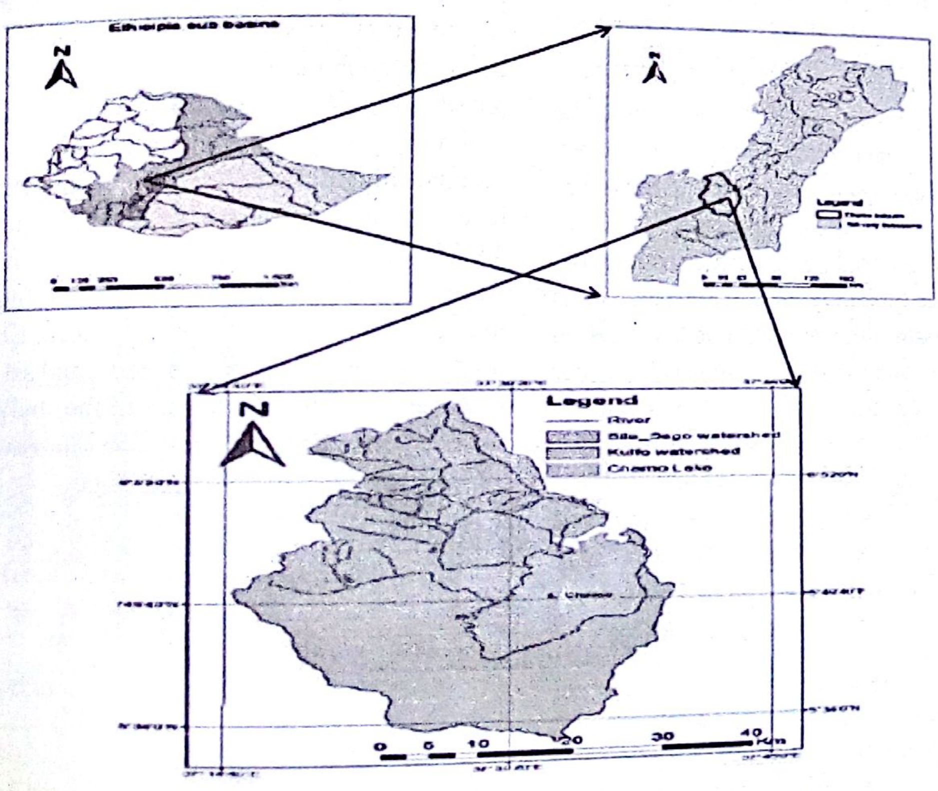


Figure 1:The study area map

Methodology

This study concerns the evaluation of Chamo Lake water balance response to climate change with the application of a semi-distributed physically based watershed model HBV in the Chamo sub basin. Statistical downscaling model (SDSM) was used for future climate generation. The procedure consists of using climatic output data from general Circulation models (GCMs) to retrieve climate scenarios. The weather generator was then used to produce daily temperature and precipitation data to serve as an input data for the HBV hydrological model to simulate runoff. The future simulated results were then compared with the base line period as a means of obtaining the change caused by climate change.

The historical climate and hydrological data have been collected from National metrological Service Agency and Ministry of water irrigation and energy that used to calibrate and validate HBV model, but before the calibration has been taken for the given model, watershed parameters are needed, these watershed parameters are watershed area, mean elevation, land use and the shape of the watershed. These parameters are taken from the output of the digital elevation model (DEM) that has been processed by Arc GIS. Taking these watershed parameters, the historical runoff and climate data calibration has been taken to determine the model parameters. Model calibration is tuning of model parameters based on checking results against observations to ensure similar response over time. This involves comparing the model outputs, generated with the use of historic meteorological observations, to recorded runoff. In this process, model parameters varied until recorded runoff patterns are accurately simulated.

In order to utilize the calibrated model for estimating the effectiveness of future potential management practices, the model tested against an independent set of measured data. This testing of a model on an independent set of data set is commonly referred to as model validation. As the model predictive capability was demonstrated as being reasonable in both the calibration and validation phases, the model was used for future predictions under different management scenarios. On the other hand the coarser climate data (GCM) are downscaled in to station level by using statistical downscaling model (SDSM 4.2.2), these downscaled data have been taken directly as an input of the model to assess the future climate change impact on hydrology of the sub-basin. ERDAS image was used to process remotely sensed Land sat **Methodology**

This study concerns the evaluation of Chamo Lake water balance response to climate change with the application of a semi-distributed physically based watershed model HBV in the Chamo sub basin. Statistical downscaling model (SDSM) was used for future climate generation. The procedure consists of using climatic output data from general Circulation models (GCMs) to retrieve climate scenarios. The weather generator was then used to produce daily temperature and precipitation data to serve as an input data for the HBV hydrological model to simulate runoff. The future simulated results were then compared with the base line period as a means of obtaining the change caused by climate change.

The historical climate and hydrological data have been collected from National metrological Service Agency and Ministry of water irrigation and energy that used to calibrate and validate HBV model, but before the calibration has been taken for the given model, watershed parameters are needed, these watershed parameters are watershed area, mean elevation, land use and the shape of the watershed. These parameters are taken from the output of the digital elevation model (DEM) that has been processed by Arc GIS. Taking these watershed parameters, the historical runoff and climate data calibration has been taken to determine the model parameters. Model calibration is tuning of model parameters based on checking results against observations to ensure similar response over time. This involves comparing the model outputs, generated with the use of historic meteorological observations, to recorded runoff. In this process, model parameters varied until recorded runoff patterns are accurately simulated.

In order to utilize the calibrated model for estimating the effectiveness of future potential management practices, the model tested against an independent set of measured data. This testing of a model on an independent set of data set is commonly referred to as model validation. As the model predictive capability was demonstrated as being reasonable in both the calibration and validation phases, the model was used for future predictions under different management scenarios. On the other hand the coarser climate data (GCM) are downscaled in to station level by using statistical downscaling model (SDSM 4.2.2), these downscaled data have been taken directly as an input of the model to assess the future climate change impact on hydrology of the sub-basin. ERDAS image was used to process remotely sensed Land sat imagine to study land use land cover dynamics of the study area. Finally the water balance analysis was done to assess the lake water balance response to climate change.

Result and Discussion

SDSM Model Calibration and Validation

The calibration was carried out from 1983-1997 for fifteen years and the reaming data from 1997-2007 were used for model verification. Twenty ensembles of synthetic daily weather series generated using NCEP-reanalysis data for the verification of the calibrated model. Maximum temperature and minimum temperature values gave a better R^2 values (R^2=0.94 and R^2 =0.95). The model develops a better multiple regression equation parameters for the maximum and minimum temperature than the precipitation (R2 =0.78). These calibration results show that the simulated maximum and minimum temperature has better agreement with the observed results than the precipitation variables. Validation was done based on 9 years simulation from 1998 to 2007. 20 ensembles (runs) of daily values were generated and the average of these ensembles was taken for comparison. During validation maximum temperature and minimum temperature values gave a better R^2values (R^2=0.90 and R^2=0.87 respectively) and for precipitation (R^2 =0.65). The downscaled model showed good performance during validation period in the cases of minimum and maximum temperatures and correlation coefficients that were found during the calibration step are more or less maintained.

HBV Model Calibration and Validation

The manual calibration process was used to calibrate the model parameters using time series data from 1983 to 1997. Data from 1998 to 2007 were used to validate the model using the input parameter set. Time series plots and the statistical measures of coefficient of determination (R^2) and the relative volume error (R.V.E) were used to evaluate the performance of the model. The predicted and observed runoff generally matched well. The results of the model calibration and validation showed reliable estimates of daily runoff with R^2 = 0.85 and R.V.E = 0.059 during the calibration period and R^2 = 0.81 and R.V.E= 0.071 during the validation period.

Climate Change Scenarios Developed for the Future

After the calibration and validation of statistical downscaling (SDSM 4.4.2) model, carried out, the daily future climate variables are projected for the next century using the HadCM3 Global Circulation Model. The projection generates 20 ensembles of daily climate variables, which are equally plausible hence; these ensembles were averaged out in order to consider the characteristics of all those 20 ensembles. Future climate scenarios downscaled for three climate variables (precipitation, maximum and minimum temperature) With the aid of statistical downscaling model the GCMs global predictors were used for development of future climate scenarios and the analysis was made for 2020s, 2050s and 2080s for both HadCM3A2a and HadCM3 B2a scenarios.

The downscaled minimum temperature in 2020s indicated that the minimum temperature will rise by 0.7 ^{0}C for A2a and by 0.9 ^{0}C for B2 scenarios. For 2050s the increment will be 1.4 ^{0}C for A2a and 1.8 ^{0}C for B2a scenarios respectively. The increment will be expected to be high in 2080s, which is 2.7 ^{0}C for A2a and 2.8 ^{0}C for B2a scenarios respectively

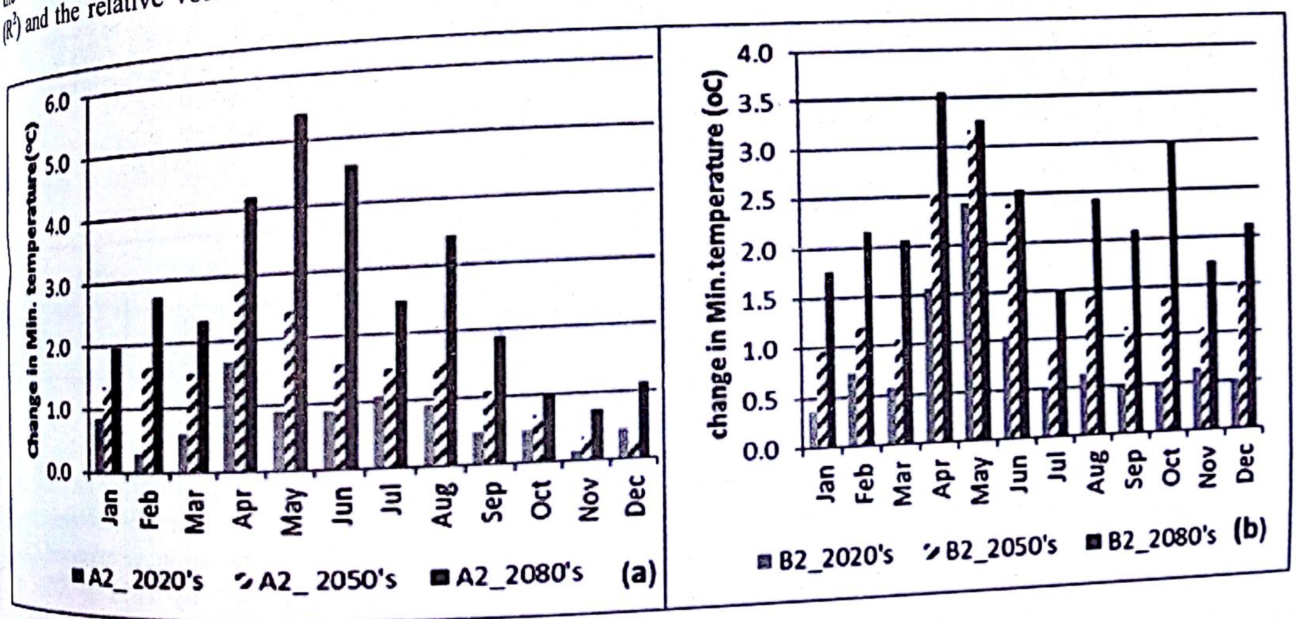


Figure 2 :(a&b): Change of downscaled monthly minimum temperature from the baseline period for HadCM3A2a and HadCM3B2a respectively

Similar to projected average monthly minimum temperature, maximum temperature also reflects increasing trend in future climate periods. The projected maximum temperature in 2020s indicated that maximum temperature will rise by 1.6 ^{0}C and 1.2 ^{0}C for HadCM3A2a and HadCM3B2a scenarios. In 2050s the increment will be 2.2 ^{0}C and 2 ^{0}C for HadCM3A2a and HadCM3B2a scenarios respectively. Whereas, in 2080s the maximum temperature will be increased by 2.9 ^{0}C and 2.5 ^{0}C for HadCM3A2a and HadCM3B2a scenarios, respectively. This shows that the future period will experience increasing trend in maximum temperature for both HadCM3A2a and HadCM3B2a scenarios. However, the increments will be less for HadCM3B2a scenario relative to HadCM3A2a scenario.

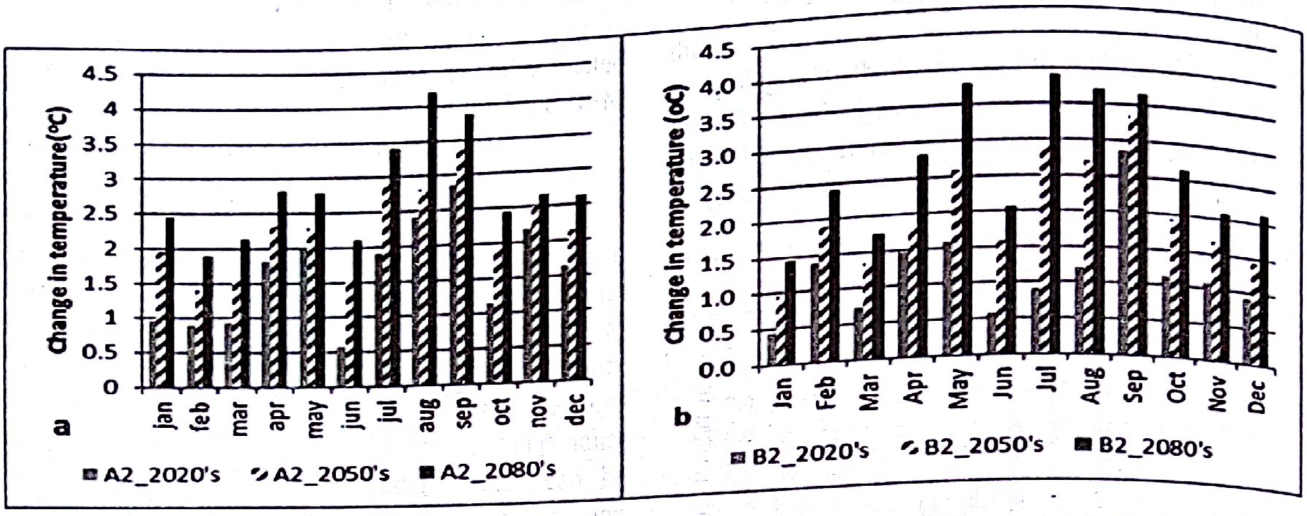


Figure 3: (a&b): Change of downscaled monthly maximum temperature from the baseline period for HadCM3A2a and HadCM3B2a respectively

Like the maximum and minimum temperature the projected precipitation does show an increase trend. The precipitation experiences a mean annul increase in amount by 9.8%, 15% and 22% for A2a scenario at 2020s, 2050s and 2080 respectively. But, the precipitation exhibits a mean annual increase in amount by 4.8% and 9.7% for B2a scenario at 2020s and 2050s and by 12.5% in 2080s. Generally, for both A2a and B2a scenario the precipitation shows an increasing trend.

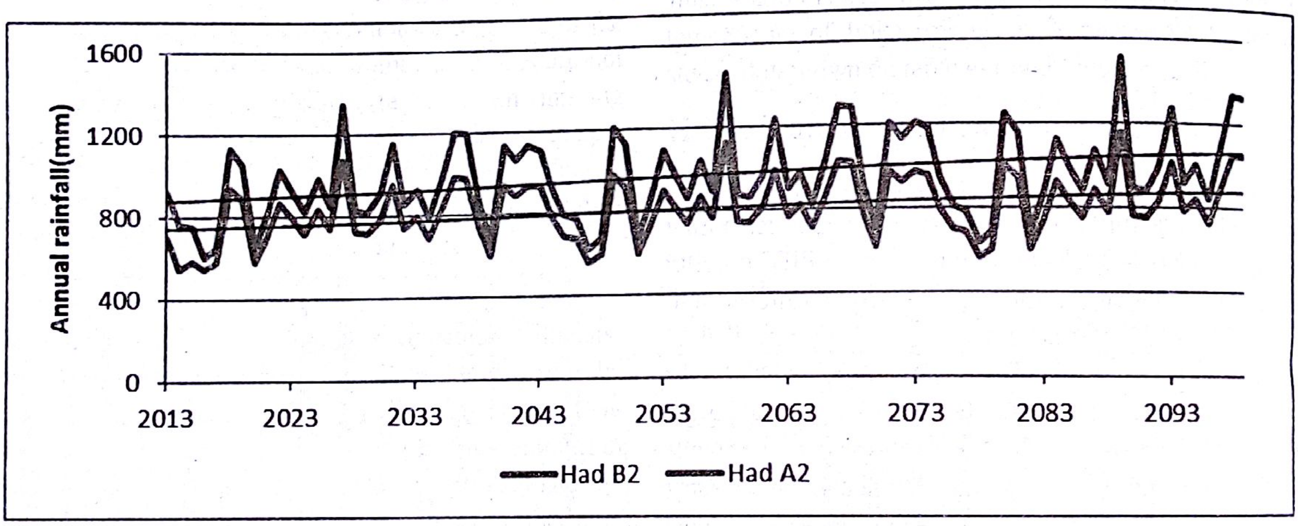


Figure 4: The downscaled trend of precipitation for the next century

The projection of average annual Lake Chamo evaporation (Figure 5) and the percentage variation (Figure 6) shows increases in amount by 12.4% in 2020s; by 13.8% in 2050s and 15.2% increase is projected in 2080s under the HadCM3A2a emission scenario. The rate of monthly lake water evaporation was found to increase relatively at higher rate during the month of Feb to May in 2020s and during the months of Jun to September in 2050s and during July to December for 2080s under A2a scenario. In the case of B2a scenario the evaporation is expected to increase by 14.8 % in 2020s and by 16% in 2050s and 16.4% increase in change is expected by 2080s under B2a scenarios.

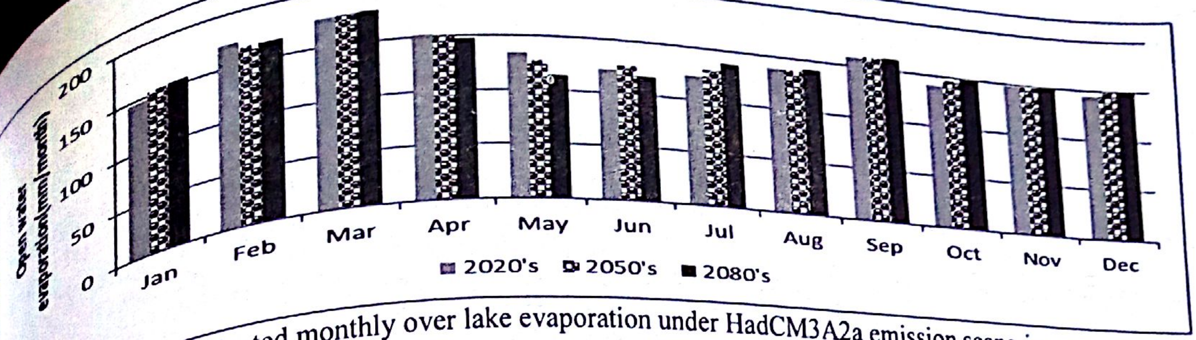


Figure 5: Projected monthly over lake evaporation under HadCM3A2a emission scenario

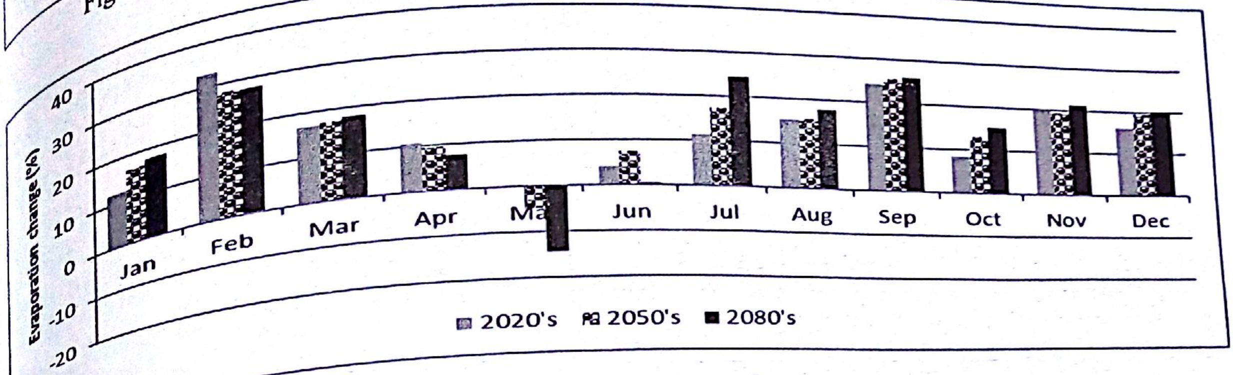


Figure 6: Projected monthly percentage change in Lake Chamo evaporation under A2a emission

Impacts of climate change on kulfo outflow.

The Kulfo watershed inflow volume to Lake Chamo was projected by using the downscaled climate variable as an input to the HBV-hydrological model. The impact of climate change was analyzed taking the 1983-2007 river flow as the baseline flow against which the future flows for the 2020s, 2050s and 2080s compared. In the 2020s for the HadCM3 A2a scenario, the flow volume may show an increase for wet months by 7.5% and decrease by -4.8% for dry months. In the 2020s for HadCM3 B2a scenario, almost the same monthly effect as the A2a scenario of 2020s was observed. But the decrease in monthly flow volume is expected to reach up to -5.4% and the increase might reach up to 6.3%. In 2050s for HadCM3 A2a scenario the inflow increase by 9.6% and decrease by-3.4% and for B2a scenario -7.4% decrease and 4.5% increases in flow volume was exhibited. In 2080s, an increasing trend for HadCM3A2a and decreasing trend for HadCM3B2a scenarios will be expected. In monthly bases the A2a scenario will expect to increase up to10.6% and decrease up to -3.8%. However, in 2080s according to B2a scenario, the pattern of monthly flow volume change may increase up to 8.2% and decrease up to -5.8%.Figure 37 and 38 shows percentage change in monthly Kulfo River out flow in respect to baseline period for both the HadCM3 A2a and B2a scenarios.

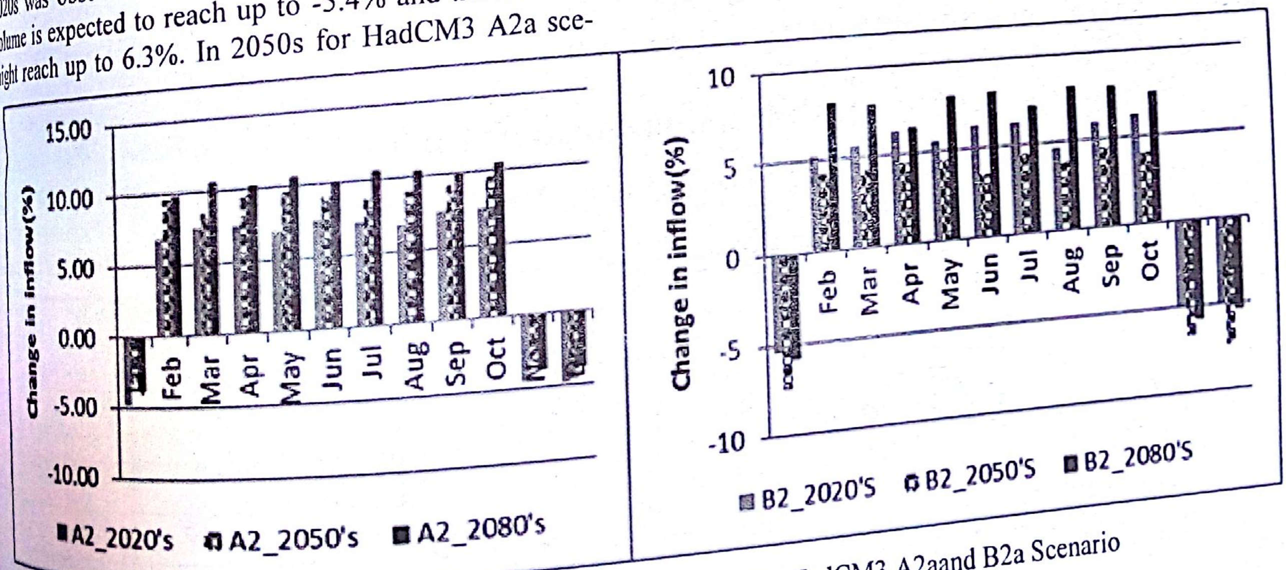


Figure 1: Percentage change in monthly kulfo out flow for HadCM3 A2aand B2a Scenario

Projected Lake Water balance Analysis

Table (8) shows summary of the annual water balance components with expected storage change in percentage. The water balance was estimated based on the inflow and the out flow of the Lake Chamo. The inflow component is the summation of the over-lake precipitation and the kulfo watershed runoff. The outflow component is over –lake evaporation.

Table 1: The Water balance components (mm/year) with expected percentage changes (%)

Water balance components	Base period	2020's		2050's		2080's	
		A2a	B2a	A2a	B2a	A2a	B2a
Over Lake precipitation	929.07	953.8	901.7	1020.2	963.4	1142.0	1004.7
Kulfo runoff	233.33	213.2	211.0	217.4	207.3	218.6	213.9
Over Lake evaporation	1619.95	1756.2	1735.1	1769.3	1776.5	1765.4	1762.7
Storage change	-457.56	-589.2	-622.4	-531.6	-605.8	-404.8	-544.1
Percentage change		-28.5	-35.7	-15.9	-32.1	-11.7	-18.7

As indicated in Table 1 the Lake water balance and its percentage change was computed for the three future time horizons (2020's, 2050's and 2080's) under both HadCM3 A2a and B2a emission scenario. In 2020's the lake water storage decreases by 28.5% and -35.7% for HadCM3 A2a and B2a scenario respectively. The lake water storage will be expected to decrease for A2a and B2a scenario by -15.9% and -32.1% respectively in 2050's. In 2080's -11.7% and -18.7% decrease in Lake water storage will be expected for both A2a and B2a emission scenario respectively. As shown in the above table the projected precipitation and Kulfo river inflow to Lake Chamo shows increasing values in the future time horizon, however due to climate change the over lake evaporation is much larger than the Lake total inflow .This Large lake water storage change result can be attributed to the lack of direct measurement of accurate evaporation rate or the fact that we assumed net groundwater flux and inflow from the ungagged catchment to be negligible because of total diversion of Sile ,sego and wozeka river for irrigation consumption. This result is argued with (Seleshi B.,2000) the Lakes Chamo might disappear or substantially shrink due to the following major reasons. These are effect of natural and anthropogenic condition: increase evaporation, which is associated to climatic change, Siltation and complete fill up of the water carrying capacity of the Lakes, Overuse of water resource for consumptive purposes and Misuse of the water resource and pollution. The area experiences moist sub-humid to semi-arid climate with evapotranspiration exceeding rainfall (Makin et al. 1975).The rise in temperature at local level might have enhanced evapotranspiration rates contributing to large water loss.

Analysis of land use/cover changes

Table 2: Change in area (km2) of the land use/cover types for the Chamo Basin

Land use/cover type	Year (1986)		Year (2000)		Year(2011)		Change (%) b/n 1986 and 2011	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	2000	2011
Water body	324	14.27	310	13.7	296	13.04	-4.32	-8.64
Forest	41	1.8	27	1.19	23	1.01	-34.15	-43.9
Farmland	737	32.47	787	34.7	919	40.5	+6.78	+24.7
Shrub land	1168	51.45	1146	50.5	1032	45.5	-1.88	-11.6

The analysis of Land sat image with acquisition years (1986, 2000, and 2011) was summarized as follows .The study area under consideration is included in the Abaya Chamo Basin. The major land use/cover types in the basin are indicated in Table 2. Figures 39 shows the change in the land use/cover of the basin and the quantitative description is summarized in Table 2. Farm land have been increased by 6.78% and 24.7%, shrub land has been decreased by about 1.88% and 11.6% respectively between 1986 and 20011. The forest cover of the study area has been decreased by -34.15% in 2000 and –43.9% in 2011.Similarly the lake Chamo water body has been decreased by -4.32% and -8.64% respectively in 2000 and 2011. This could imply the decline of water storage of the lake. As indicated in (Alemayehu and Raju,,2011) the Lake Chamo has shrunk by 14.42%(50.12sq.km) of the lake surface area that was in 1965 due to this the Lake area earlier covered with water is now converted to grazing, farm land and site to dig special type of clay used as salt lick. An increase in the rate of forest conversion contributes a decrease in the dampening effect on CO2 emissions; an increase in CO2 emissions causes severe climate change.

Conclusion

The result of climate projection reveals that the SDSM model has very good ability to replicate the historical maximum and minimum temperature for the observed period; but less for the observed precipitation with the simulated precipitation due to its conditional nature and high variability in space.

The results from the applied statistical downscaling model indicate that both the minimum and maximum temperature show an increasing trend in all the future time horizons for both A2 and B2 scenarios. The average annual minimum temperature will be increased by 1.6°C and 1.8°C for A2 and B2 scenario respectively towards the end of this century. The maximum temperature will also increase by 2.2°C and 2.6°C for A2 and B2 scenario respectively within the same time period. Climate change scenarios for Africa, based on the results from several General Circulation Models using the data collected by the Intergovernmental Panel on Climate Change Data Distribution Centre (IPCC-DDC) indicate that future warming across Africa ranges from 2°C (low scenario) to 5°C (high scenario) by 2100. Therefore the result obtained from SDSM lies within the range of IPCC recommendations.

The projected precipitation reveals an annual increase for all the three time horizons (i.e. 2020s, 2050s and 2080s) in both A2a and B2a emission scenario. This results are within the limits of the expected projection carried by the recent (IPCC, 2013) working group two assessment report for Africa content.

The evaporation from the open water generally shows an increasing trend i.e. it exhibits an average annual increase of 14 % for A2a emission scenario and 15.7% increase for B2aemission scenario at the end of the next century.

The result of HBV hydrological model calibration and validation indicates that the model simulates the runoff in reasonably good manner with the model performance criteria of Nash and Sutcliffe value R^2=0.85 for calibration and R^2= 0.81 for validation. Hence, it is concluded that the HBV is an acceptable hydrological model for this study, in order to project the inflow for future climate condition.

The future climate change impact on Kulfo river flow was analyzed under both HadCM3 A2a and B2a emission scenarios. The result shows that the runoff will increases for wet months by 9.2% and 6.3% and decreases for dry months by -4% and- 6.2% for A2a and B2a scenarios respectively .This result can be interpreted by nothing but the predicted increase in rainfall values in the future and less infiltration during the wet seasons due to the agriculture and pasture land use system.

Lake water balance and its percentage change was computed for the three future time horizons (2020's, 2050's and 2080's) under both HadCM3 A2a and B2a emission scenario which shows that the Lake water storage change will decreases in all future time horizons.

The analysis of Land sat imager for acquisition year 1986, 2000 and 2011 indicated that the water body/lake/area decreased by -4.32% and -8.64% .

Acknowledgements

Special thanks to my advisor Dr.Ing .Kassa Tadele for his valuable support in guidance, encouragement, suggestions and particularly the good and positive discussions we had to clear many doubts and to broaden my understanding about the topic.

References

AlemayehuHailemicael and Solomon Raju (2011).Sustainable utilization of Lake Chamo Biodiversity resource, Ethiopia.

Cubash, U., (2001). Projections of Future Climate Change in Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third

Assessment Report of the Intergovernmental Panel on Climate

IPCC (2007). Technical Summary 2007: The Scientific Basis. Technical Summary of the Working Group I Report [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson]. Cambridge University Press, Cambridge,United Kingdom and New York ,NY,USA,94pp.

SeleshiBekeleAwulachew (2000). Investigation ofWater Resources Aimed at Multi Objective Developmentwith Respect to Limited Data Situation.The Case of the Abaya - ChamoBasin.Ph. D. Dissertation.Dresden University of Technology.

TenalemAyenew (2002). Recent changes in the level of Lake Abiyata, central main Ethiopian Rift. Department of Geology and Geophysics, Addis Abebauniversity, Addis Abeba.URL:

TenalemAyenew (2009). Natural Lakes of Ethiopia.AddisAbeba University press, AddisAbeba.

USAID (2005).Ethiopia Southern Nations, Nationalities and Peoples Region (SNNPR) Overview of Livelihood Profiles

Assessment of Groundwater Potential Zones in Baro Basin using GIS and remote sensing

[1]Tegegn kassa and [2]Guche Gule

Department of Water Resources and Irrigation Engineering,

Arba Minch University

tegegnkassa@gmail.com ; +251-913428784

Abstract

Baro river basin, located in southwest of Ethiopia is the largest sub basin of Baro-Acoobo basin. For the proper utilization and management of groundwater resource in the basin, it required to know its spatial distribution. Hence, geographic information system and remote sensing techniques were used to analyze the groundwater system based on seven selected groundwater influence factors thematic maps. The thematic maps we used were geology, soil, lineament density, drainage density, rainfall distribution, and slope and land use maps. Lineament and land use maps were prepared through the process of remote sensing techniques from Landsat TM imagery using ERDAS imagine and PCI Geomatica software. Other thematic maps were prepared using Arc GIS 9.3 from DEM and previous prepared soil and geology maps for each maps weight value were estimated by using PriEst software after assigning weight value of domain effect by using pairwise comparison based on Saaty's analytical hierarchy process. Finally thematic layers were integrated in Arc GIS 9.3 based on estimated weight values. In the basin, four groundwater potential zones were identified; namely: excellent, good, moderate and poor. Excellent groundwater potential zones are associated with areas of alluvial deposition, flat and sand dominant soil group of western part of the basin; north and eastern portion of basin have good and moderate potential zone. Poor potential zone is in areas of mountain which have steep slope and high drainage density in center of the basin.

Key words: Baro basin, Groundwater potential, GIS, remote sensing, thematic map, AHP

Introduction

Groundwater is the important component to many hydrological processes which sustain spring discharges and river base flow, lakes and wetlands, transport dissolved chemicals, facilitate weathering as well as provide habitat to microorganisms. The dominant role of groundwater resources is clear; their use is fundamental to human life and economic activity, and used as poverty reduction tool in developing countries and can be delivered to poor communities far more cheaply, quickly and easily than the conventional canal irrigation water (IWMI, 2001).

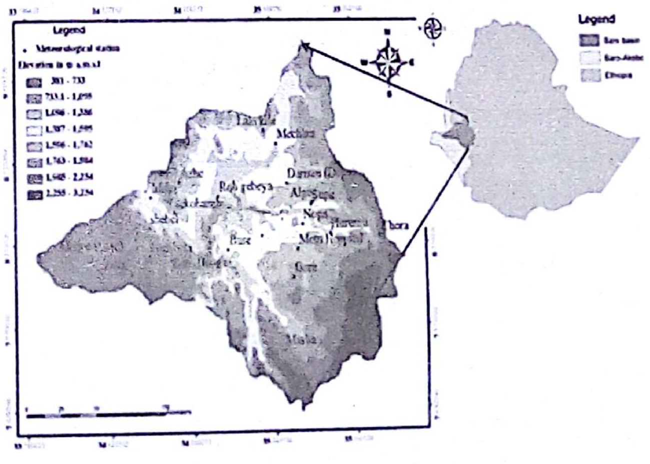
Groundwater resource in Ethiopia is estimated 2.6 billion m^3 but later revised it to be about 28 billion m^3 (Seleshi,*etal*,2010) and other organizations have estimated it to be above 28 billion m^3 (seifu, 2012).

Baro-Akobo basin groundwater resource classified in two main types of aquifers; one associated with fracture and crush zones in the basement Complex rocks and the other in the Pliocene to Quaternary alluvium, an unconsolidated sedimentary porous medium (Callist, 2012).Estimated groundwater potential of Baro-Akobo basin is 0.28 Bm^3 with annual recharge 0.13 Bm^3 (Seleshi,*etal*, 2007).

Study area

Baro River basin is the major basin in Baro Akobo is located in the southwest of Ethiopia at 33.46^0 E up to 36.17^0 E longitude, and $7.20\ ^0$ N up to $9.20\ ^0$ N latitude. It covers about 26,049 km^2.The basin is characterized by mountainous terrain and falls in the altitude range of below 380 m to over 3000 m a.m.s.l. with 42% in between 1000 m and 2000 m .m.s.l. The eastern two-third of the basin area lies between 1,000 m and 2,400 m a.m.s.l. and gently sloping plain lies in the western between 380 m and 500 m a.m.s.l.

Figure 1:- Map of Baro basin



Baro basin has a varied climate conditions due to its wide elevation differences It has been observed that rainfall and temperature are correlated with altitude. As a result mean monthly average temperature ranges from 17.5 °C on highlands to around 27.5 °C on the western low lands, with an overall maximum temperature range from 24 to 35 °C and minimum temperature from 10 to 20°C.

Material and methods

Data collection

The following spatial (image) data and historic time series of meteorological data were collected for groundwater potential.

Published and non-published literatures were also used as input to complete this study.

Meteorologicai data: - Ten to seven years starting from 2003 to 2013 G.C of recorded mean monthly values of precipitation data were used.

Remote sensing data:- Landsat Thematic Mapper (TM) images and digital elevation model

Existed maps:-soil and geology maps

Borehole data:- well location, well yield and static water level

Data analysis

The methodology carried out to achieve the objectives is summarized in the flow chart in Figure 2. Groundwater potential studies were conducted in four steps. These were preparing thematic maps, assigning weight, integrating thematic maps and obtaining final result. In general three applications were applied namely; geographic information system application, remote sensing application and analytical hierarchy process application.

Geographic information system (GIS) application Geographic information system was widely used in this study for thematic map preparation. Geology and soil map were clipped, the coordinate system was projected and reclassified by using Arc map software.

Drainage network and density were done using GIS after analyzing DEM through the process of fill, creating flow direction, identifying flow accumulation, drainage network extraction, stream ordering and finally drainage density map was prepared using spatial analysis tool. Slope map and rainfall distribution map preparations were carried out through the process of geographic information system. GIS technique was also employed in reclassification and finally in integration of all thematic maps using spatial overlaying techniques by weight overlay tool.

Remote Sensing Application

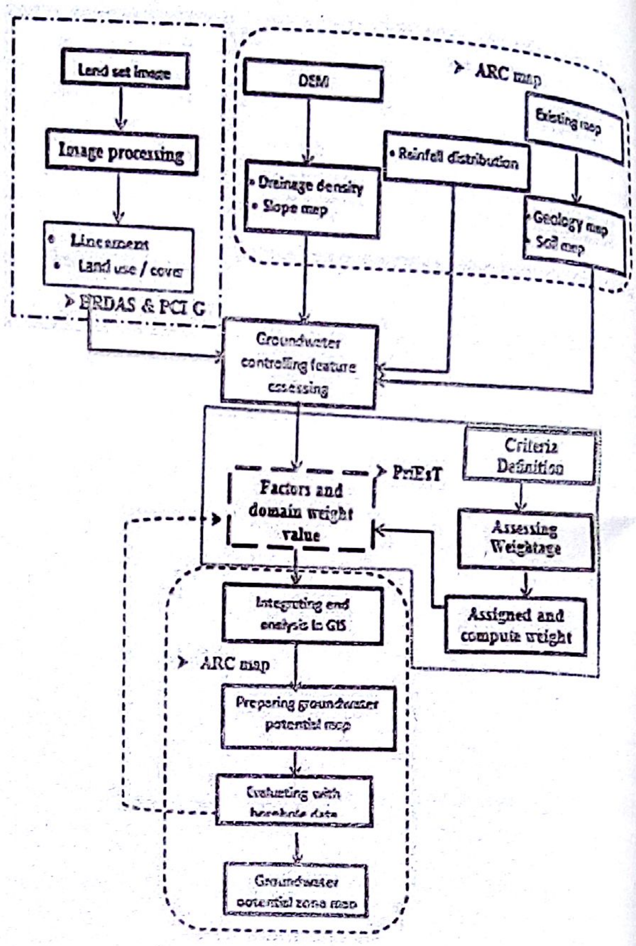


Figure 2:- Flow charts groundwater potential study

Landsat Thematic Mapper (TM) images were used for land cover classification and lineament extraction. Land use /cover was classified by ERDAS imagine 2014 software based on supervised classification method through different process. Lineaments were extracted using remote sensing software known as PCI Geomatica. During the process of lineament extraction an appropriate bands identified and in algorism library tool geological /geophysical analysis function was used for automatic lineament extraction.

Analytical hierarchy process (AHP) application

PriEsT software was used to apply analytical hierarchy process during estimation of weight values. In the process of estimation each groundwater controlling features from thematic maps was considered during criteria definition.

Assigning individual weight and consistency ratio value checked after criterial definition and eigenvector estimation method was selected then after factor and domain weight value was estimated.

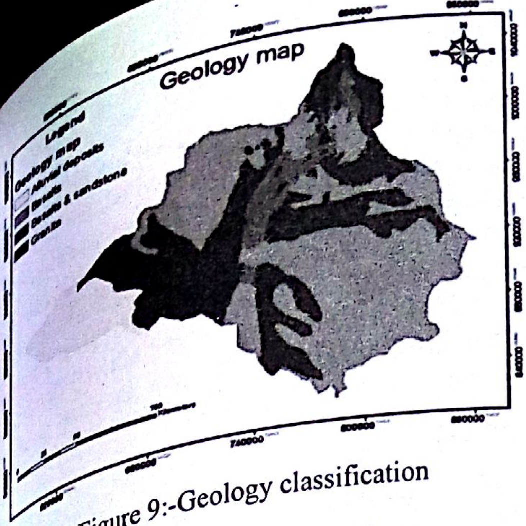


Figure 9:-Geology classification

Thematic map integration

Weighted overlay technique was used for applying a common scale of values to diverse and dissimilar input to create an integrated analysis. Geographic problems often require the analysis of many different factors which are not equally important. The information exists in different raster with different value scales: slope, geology map, soil map, drainage density, rain fall distribution, lineament and land use/cover.

Each thematic map such as geology, geomorphology, lithology, soil, drainage density, lineament, slope, and land use/land cover provides certain clue for the occurrence of groundwater. Therefore, this information's were integrated through the application of GIS. Various thematic maps were reclassified on the basis of weight assigned and brought into the weighted overlay tool in Arc GIS.

The Weighted Overlay tool let to take all groundwater influencing factors into consideration. It reclassifies values in the input raster onto a common evaluation scale of suitability or preference scale based on the given weight. The input raster thematic maps were weighted by importance to create groundwater potential zone and added together to produce a final output.

Result and Discussion

Groundwater controlling features

Higher weight value was estimated for slope and geology formation maps with the values 23.3 and 20.4 respectively Table 1. Due to flat area that cover wide areas of the basin and geological formations that are favorable for the formation of groundwater potential existed in basin, like alluvial deposition and basalt formation, it led geologic weight value to became the second higher.

Table 1:-Estimated factors and domain weight value

Baro basin, known as the highest rainfall area, rainfall distribution plays a great role for the formation of potential areas so the third highest weight values estimated was for basin rainfall. The estimated weight value of Land

Factors	Factors weight	Domain of effect	Domains weight
Land use land cover	11.7	Water body	0.42
		Wetland	0.3
		Forest	0.14
		Shrubs	0.07
		Grass land	0.05
		Agricultural land	0.02
Soil	11.4	Gravel	0.63
		Sand	0.28
		Clay	0.1
Rainfall	16.2	Very High	0.37
		High	0.29
		Medium	0.22
		Low	0.13
Geology	20.4	Alluvia deposition	0.51
		Basalts	0.3
		Basalts & Sandstone	0.14
		Granite	0.05
Drainage density	7.6	Excellent	0.51
		Good	0.22
		Moderate	0.14
		Poor	0.09
		Very poor	0.03
Slope	23.3	Flat	0.43
		Gentle	0.3
		Moderate	0.16
		Steep	0.07
		Very steep	0.04
Lineament density	9.4	Excellent	0.39
		Good	0.34
		Moderate	0.17
		Poor	0.07
		Very poor	0.03

cover map and soil map 11.7 and 11.4 respectively. Because of large area covered for agricultural activity and major soil type was clay in basin their importance to groundwater potential is less.

Lineament and drainage density maps was the minimum estimated weight values Table 1. The influence of

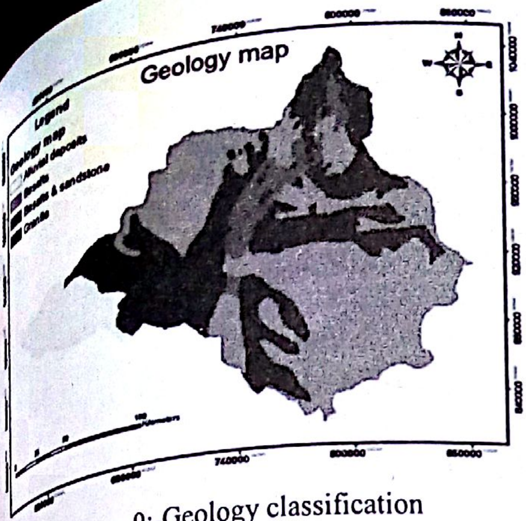


Figure 9:-Geology classification

Thematic map integration

Weighted overlay technique was used for applying a common scale of values to diverse and dissimilar input to create an integrated analysis. Geographic problems often require the analysis of many different factors which are not equally important. The information exists in different raster with different value scales: slope, geology map, soil map, drainage density, rain fall distribution, lineament and land use/cover.

Each thematic map such as geology, geomorphology, lithology, soil, drainage density, lineament, slope, and land use/land cover provides certain clue for the occurrence of groundwater. Therefore, this information's were integrated through the application of GIS. Various thematic maps were reclassified on the basis of weight assigned and brought into the weighted overlay tool in Arc GIS.

The Weighted Overlay tool let to take all groundwater influencing factors into consideration. It reclassifies values in the input raster onto a common evaluation scale of suitability or preference scale based on the given weight. The input raster thematic maps were weighted by importance to create groundwater potential zone and added together to produce a final output.

Result and Discussion

Groundwater controlling features

Higher weight value was estimated for slope and geology formation maps with the values 23.3 and 20.4 respectively Table 1. Due to flat area that cover wide areas of the basin and geological formations that are favorable for the formation of groundwater potential existed in basin, like alluvial deposition and basalt formation, it led geologic weight value to became the second higher.

Table 1:-Estimated factors and domain weight value

Baro basin, known as the highest rainfall area, rainfall distribution plays a great role for the formation of potential areas so the third highest weight values estimated was for basin rainfall. The estimated weight value of Land

Factors	Factors weight	Domain of effect	Domains weight
Land use land cover	11.7	Water body	0.42
		Wetland	0.3
		Forest	0.14
		Shrubs	0.07
		Grass land	0.05
		Agricultural land	0.02
Soil	11.4	Gravel	0.63
		Sand	0.28
		Clay	0.1
Rainfall	16.2	Very High	0.37
		High	0.29
		Medium	0.22
		Low	0.13
Geology	20.4	Alluvia deposition	0.51
		Basalts	0.3
		Basalts & Sandstone	0.14
		Granite	0.05
Drainage density	7.6	Excellent	0.51
		Good	0.22
		Moderate	0.14
		Poor	0.09
		Very poor	0.03
Slope	23.3	Flat	0.43
		Gentle	0.3
		Moderate	0.16
		Steep	0.07
		Very steep	0.04
Lineament density	9.4	Excellent	0.39
		Good	0.34
		Moderate	0.17
		Poor	0.07
		Very poor	0.03

cover map and soil map 11.7 and 11.4 respectively. Because of large area covered for agricultural activity and major soil type was clay in basin their importance to groundwater potential is less.

Lineament and drainage density maps was the minimum estimated weight values Table 1. The influence of

Assessment of Runoff Potential for Flood based Farming (Case Study of Lower Omo Ghibe Sub-basin, Ethiopia)

Tenaw Endalamaw (MSc.) Dilla University, Bogale G/Mariam (PhD) Arba Minch University, ErmiasAlemu (PhD candidate)

Abstract

Omo-Ghibe basin with total catchment area of about 79000 km^2 is one of the major river basins in Ethiopia. Flood based farming has been practiced in the lower Omo-Gibe basin where evapotranspiration greatly exceeds rainfall, whereas the same area has experienced serious flooding problems in recent years. The effect of regulated flows to generate hydropower from Gibe III reservoir on the potential of flood based farming in the lower Omo-Gibe basin was investigated to enhance sustainable development of the marginalized communities. The Digital Elevation Model was used to extract the physical characteristics of the watershed using HEC-GeoHMS. HEC-HMS was used to estimate discharges and runoff hydrographs, and to simulate the flood potential of the area for different flow conditions. Water surface profiles for minimum, maximum, and regulated flows were analysed using HEC-RAS and flood inundation mapping were prepared to understand flood recession farming during 21 years study period (1989–2009).The peak discharges generated by HEC-HMS for 2006 was 3252 m^3/s, whereas the lowest discharge for 1989was 2398 m^3/s. The output of HEC-GeoRAS and HEC-RAS showed that the maximum depths of flood inundation, which cover parts of Selamago, Dassenech, Gnangatom and Hamer Woredas, were 1.05m, 2.3m, and 1.2m for minimum, maximum regulated flows, respectively. The total existing flood inundation area during the study period with minimum flow in 1989 was 107 Km^2 and with maximum flow in 2006 was 182 Km^2. However, the future flood inundation area with regulated flow will be about 111 Km^2.This result shows the necessity of livelihood strategy for betterment of life of the pastoral farming community.

INTRODUCTION

Background of the study

Flood based farming is a unique form of water resource management that has been practiced in arid and semi-arid regions where evapotranspiration greatly exceeds rainfall. It uses unpredictable and occasional destructive water supply from ephemeral streams and perennial rivers for Crop, rangeland and agro-forest production, domestic and livestock water supply, and recharging groundwater. Hydrologic models are used to estimate the peak discharge and volume of runoff/runoff hydrographs. Establishing a rainfall-runoff relationship is the central focus of hydrologic modeling from its simple form of unit hydrograph to rather complex models based on fully dynamic flow equations (Moreda, 1999)

This study currently focused on application of a GIS based semi-distributed watershed model (HEC-HMS) in the Lower Omo Ghibe sub basin to establish rainfall runoff modeling for the determination of important hydrologic design parameters (peak discharge and runoff volume/runoff hydrographs) in order to use them as input for HEC-RAS hydraulic model for flood inundation mapping and assessment of flood recession farming.

Problem Statement

Floods have caused, and continue to cause, serious economic and environmental losses. This can be proven by the seasonal observed flood problems in the basin, more vividly the flooding at the river of lower Omo which causes the loss of land, crop and infrastructure due to the flood are a few to mention. However, if floods are well managed, they can serve as a source of livelihood.

To minimize the risk of the flood, estimating the fundamental hydrological design parameters for design of storm water drainage structures by applying a proper model should be done the watershed. Without understanding of the hydrology of the watershed well, it is difficult to identify intervention points and recommend a proper and scientific solution to alleviate the problem. Problem Statement

Floods have caused, and continue to cause, serious economic and environmental losses. This can be proven by the seasonal observed flood problems in the basin, more vividly the flooding at the river of lower Omo which causes the loss of land, crop and infrastructure due to the flood are a few to mention. However, if floods are well managed, they can serve as a source of livelihood.

To minimize the risk of the flood, estimating the fundamental hydrological design parameters for design of storm water drainage structures by applying a proper model should be done the watershed. Without understanding of the hydrology of the watershed well, it is difficult to identify intervention points and

recommend a proper and scientific solution to alleviate the problem.

Therefore, this research is necessitated to establish a Rainfall -Runoff Modeling for estimation of hydrologic design parameters (peak discharge and runoff volume/ runoff hydrographs) using a GIS based semi distributed hydrological model (HEC-HMS) and to compute water surface profile for different periods using HEC-RAS hydraulic model and to assess flood inundation area of lower Omo sub basin.

Objectives of the Study

General Objectives

The overall objectives of this study is to assess existing and future potential of flood base farming in Lower Omo Ghibe sub- basin to enhance sustainable development of the marginalized communities (pastoralists).

Specific Objectives

The following sets of specific objectives are also an integral part of the study:

- To estimate mean annual runoff potential of lower Omo Ghibe basin,
- To identify the existing situations of the flood based farming system in the lower Omo Ghibe basin, and
- To recommend appropriate options for flood based farming in regulated flood released from the cascade reservoirs.

DESCRIPTION OF THE STUDY AREA

General Description of Omo Ghibe Basin

The Omo-Gibe River Basin is situated in South-West of Ethiopia, between 4°00' N, 9°22' N latitude, 34°44' E, and 38°24' E longitude. The Omo River covers approximately 79,000 km^2 areas. It is an enclosed river basin that flows into Lake Turkana in Kenya, which forms its southern boundary (Woodroofe , 1996).

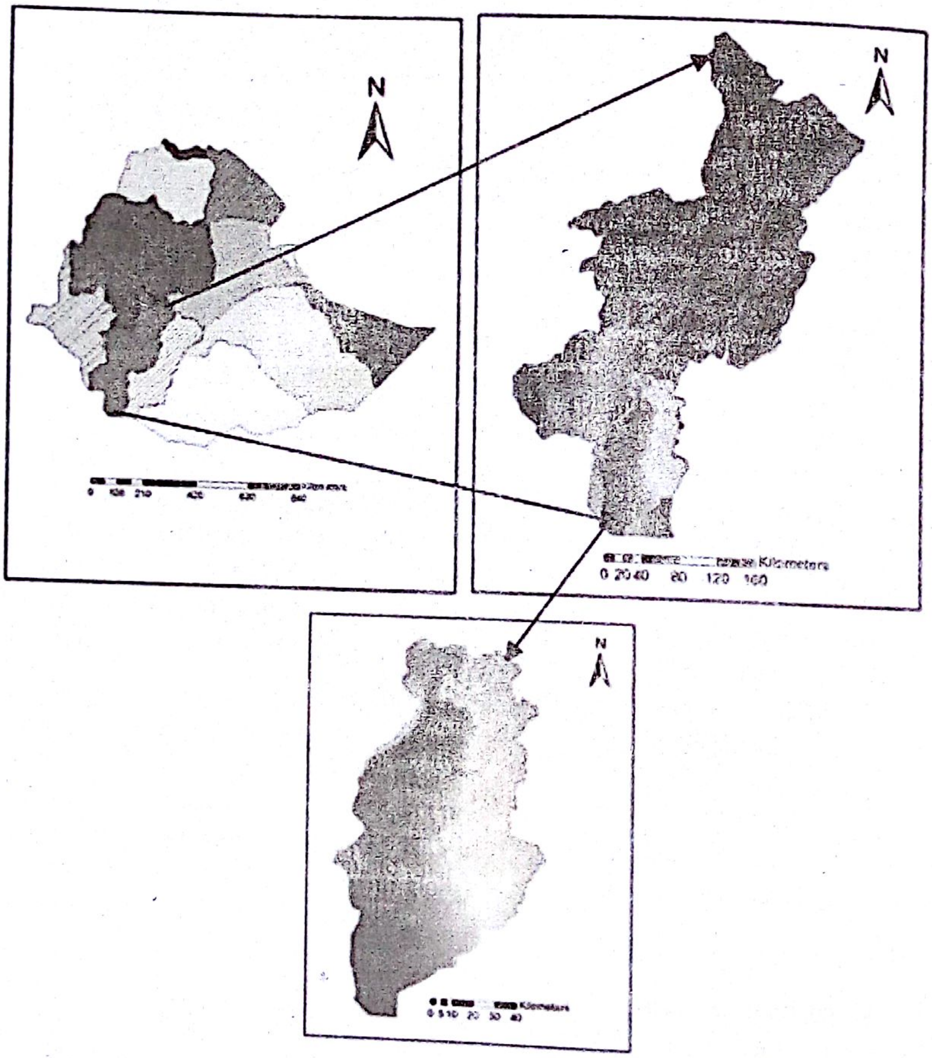


Figure 2-1: Areal description of Study Area

Lower Omo Ghibe Sub basin

The lower Omo sub- basin lies at 400-600 m a.s.l. and is composed of gently sloping alluvial-colluvial plains in the North and Alluvial plains and fans of varying degrees of dissection in the South. The lower Omo is hot and arid with an average annual rainfall of just over 400 mm. The area is semi- arid bush, interspersed with grasses, varying in density from thick bush by the river to light bush elsewhere and occasional open grass plains (Woodroofe, 1996).

The current population density is very low. There are few significant permanent settlements, mostly east of the river Omo Rate, Turmi, Dimeka, Hana and the Omo delta to the east of the river and Kibish Wells to the west. The delta area is a particular situation, benefiting both from extensive recession cultivation and from an apparent reduced tsetse presence, presumably due to the absence of bush habitat (Woodroofe, 1996).

MATERIAL AND METHODS

The methodology used in this study includes (1) collection of data from different organization and analysis of this data (2) Watershed delineation using Arc-Hydro and HEC-GeoHMS for initial parameter estimation for HEC-HMS (3) Flood inundation mapping by using HEC-GeoRAS and HEC-RAS.

General Methodology

Some of the materials used in this study are:- Instat version 3.36, statistical software was used forr conversion of daily hydro-metrological data in to monthly and yearly and also helps for the examination of any data in to extremes (mean, maximum, minimum and variance etc). Arc-GIS for spatial data analysis and making connection with Arc-Hydro and HEC-GeoHMS were used to

Hydrological Modelling for Runoff Estimation

The HEC-HMS model is a conceptual hydrologic model developed in the United States Army Corps of Engineers" hydrologic system computer program by the Hydrological Engineering Center. HEC-HMS is designed to simulate the precipitation-runoff processes of dendritic watershed systems.

HEC-HMS consists of separate models of the major hydrological processes and transports. It consists of runoff volume models, models of direct runoff (overland flow and interflow), base flow models, channel flow models (USACE, 2003).

HEC-HMS Model Setup

The main input data used for HEC-HMS are: Areal precipitation, Evapotranspiration, observed flow, base flow and different watershed characteristics obtained from ArcHydro and HEC-GeoHMS process for initial parameter estimation. After converting data from a geographic to a hydrologic data structure in the HEC-GeoHMS the next step was configuration of the HEC-HMS model.

The main procedures in HEC-GeoHMS to create hydrologic inputs for HEC-HMS hydrologic estimate initial parameter and to prepare basin and meteorological model for HEC-HMS hydrologic modeling for runoff generation. FAO ETo Calculator for Reference Crop Evapotranspiration, field survey to obtain data for reach cross-section for preparation of geometric data to be used in HEC-RAS Model. Running unsteady state simulations in HEC-RAS for the computation of water surface profile by employing discharge from HEC-HMS

Model result.

modeling are terrain pre-processing, basin processing, stream and sub-basin characteristics, hydrological parameter estimation and hydrological modeling system (HMS) were required for developing HEC-HMS model (USACE, 2003).

HEC-HMS Model Performance

The performance of the model must be evaluated for the extent of its accuracy (Goswamiet al., 2005). Hence, for this study, the model performance in simulating observed discharge was evaluated during calibration and validation by inspecting simulated and observed hydrograph visually and by calculating Nash and Sutcliffe efficiency criteria (NSE), coefficient of determination (R^2), and Percent difference /Relative Volume Error(D) were used.

Hydraulic Modeling with HEC-RAS

HEC-RAS uses a number of input parameters for hydraulic analysis of the stream channel geometry and water flow. The channel geometric description and flow rate values are the primary model inputs for the hydraulic computations. For unsteady, gradually varied flow, the basic computational procedure for computing water surface profiles between cross sections is based on the iterative solution of the energy equation. . Given the flow and water surface elevation at one cross section, the goal of the standard step method is to compute surface elevation at the adjacent upstream or downstream cross section, depending on the flow regime.

DATA PROCESSING AND ANALYSIS

Spatial Data

Digital Elevation Model (DEM) of 90mx 90m resolution, Land use/land cover, Soil and geology shape file data for the study area taken from Ministry of water and Energy. Input data for the model, catchment area, and other related spatial data were processed and delineated from the DEM with a help of Arc GIS 9.3 and Arc Hydro tools.

Meteorological Data

The meteorological data have been collected from National Meteorological Agency (NMA). The availability and quality of meteorological data such as rainfall, temperature, sunshine hours, wind speed, and relative humidity are vital for any water resource study. The daily meteorological data was collected for 19 stations depending up on the homogeneity of the pattern which can be representative to the area. The criterions for the selection of the metrological data were based on the availability of data, the data quality and their existence in Omo Ghibe basin. The data collected covers a period of 21 years (1989-2009).

Estimating Missing Precipitation Data

Most of the rainfall stations in the study area have short breaks in their records and it is necessary to estimate the missing records to keep the continuous time series of the data. Stations near lower Omo Ghibe sub basins are not uniformly distributed. As a result stations with missing data near lower Omo sub basin were filled by simple linear interpolation and normal ratio method. Filling of missing temperature, humidity, sunshine, wind speed data was done with the same procedure and method as precipitation data.

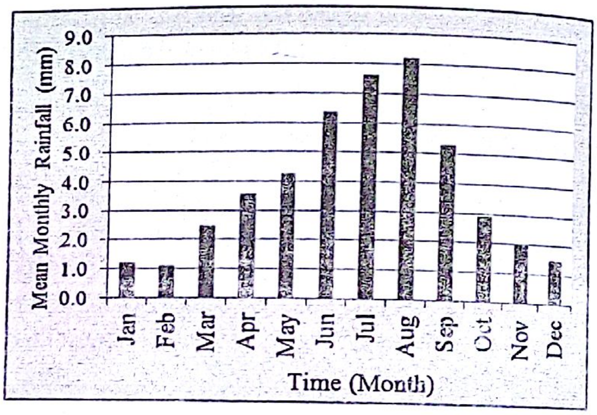
The rainfall data analysis results, together with discharges from gauged sites, were used to estimate the stream-flow at the ungauged sites in the study area. A long term average of stream-flow at gauged sites and mean daily areal rainfall of the sites were used to estimate the discharges at ungauged sites. This was performed by applying runoff coefficient of the gauged sites to ungauged sites. According to Goldsmith (2000), to estimate mean monthly runoff volume of un-gauged sites from gauged sites, catchment characteristics such as land cover, soil type, and catchment slope ranges should be similar and mean monthly river flow at the gauged sites should be available. On this Upper Lower Omo Gibe basin the gauged and un-gauged river catchments soil, slope and land cover maps was in the same basin i.e. Omo Ghibe basin. Then runoff volume per month at the ungauged site was estimated using the following equations:

$$Q_{ungauged} = \frac{A_{ungauged}}{A_{gauged}} * Q_{gauged} * \frac{P_{ungauged}}{P_{gauged}}$$

Areal Rainfall

In this study, the Thiessen polygon method was used to estimate the areal rainfall. The method assumes that the recorded rainfall in a gauge is representative for the area halfway to the adjacent gauges.

Figure 4- 1: Mean Areal Monthly precipitation for Upper



Lower Omo Valley

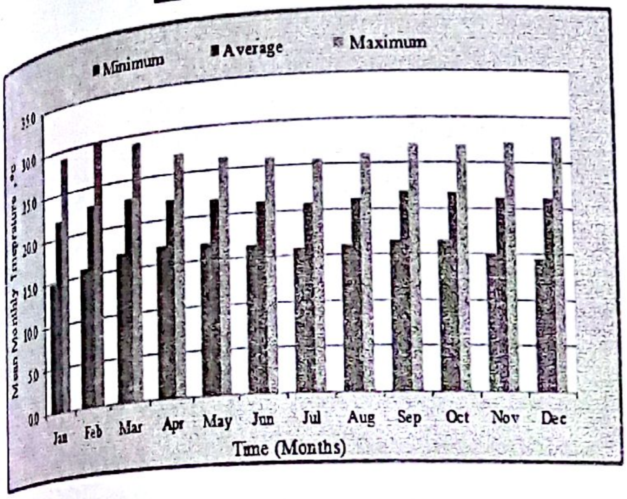
Jinka station is near lower Omo sub basin. As a result the temperature of Jinka was taken as representative for the study. It is shown on table 4-1 and Figure 4-2.

HEC-GeoRAS extensions

HEC-GeoRAS is a GIS extension that provides the user with a set of procedures, tools, and utilities for the preparation of GIS data for import into HEC-RAS and generation of GIS data from RAS output. The tools allow users with limited GIS experience to create HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and complementary data sets. Water surface profiles results may also be processed by visualize inundation depths and boundaries. HEC-GeoRAS creates lower Omo Ghibe geometric data for import into HEC-RAS and enables viewing of exported result from RAS. Prior to performing hydraulic computations in HEC-RAS, the geometric data was imported and completed and maximum, minimum and regulated flow data was entered. After performing the hydraulic computations, lower Omo exported water surface and velocity

Table 4- 1: Mean Monthly temperature of Jinka stations

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MinT°	14.9	15.8	16.8	17.1	16.9	16.4	15.9	16.2	16.5	16.5	15.0	14.5
Ave T°	21.9	22.8	22.9	22.2	21.7	21.1	20.7	21.1	21.8	21.6	21.1	21.2
MaxT°	29.0	29.9	29.0	27.2	26.4	25.9	25.4	26.1	27.0	26.8	27.2	27.9



results from HEC-RAS was imported back to the GIS using HEC-GeoRAS for spatial analysis. GIS data is transferred between HEC-RAS and ArcGIS using a specifically formatted GIS exchange file (*.sdf).

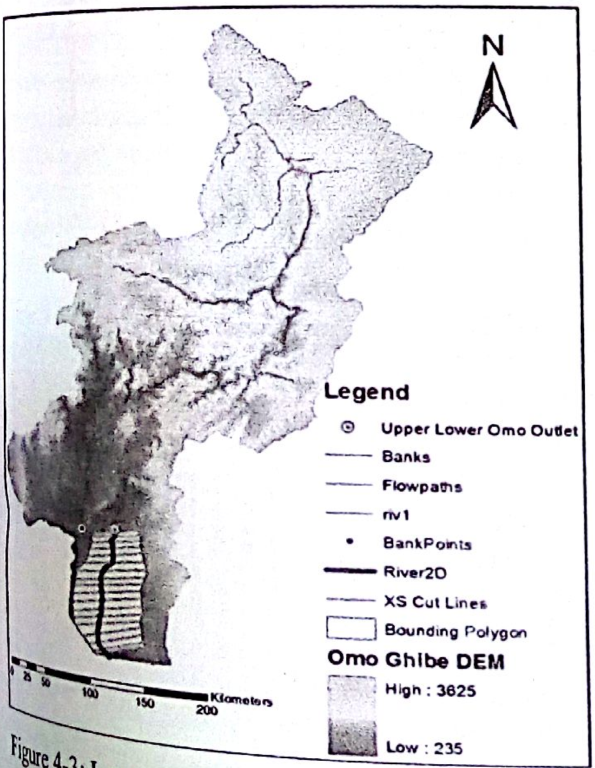


Figure 4-3: Lower Omo Ghibe sub basin HEC-GeoRAS Processing and DEM

HEC-RAS Processing

The objective of the hydraulic modeling process was to convert the flow values calculated into water surface elevations along the stream reach and adjoining flood plain. Hydraulic Modeling using HEC-RAS computer program is done for Omo Ghibe River where over topping of riverbank is prevailed in lower of the River. For each HEC-RAS project, there are three required components--Geometry data, Flow data, and Plan data. Geometric data consists of establishing the connectivity of the river system (River System Schematic), entering cross section data, defining all the necessary junction information, adding Hydraulic structure data and cross section interpolation.

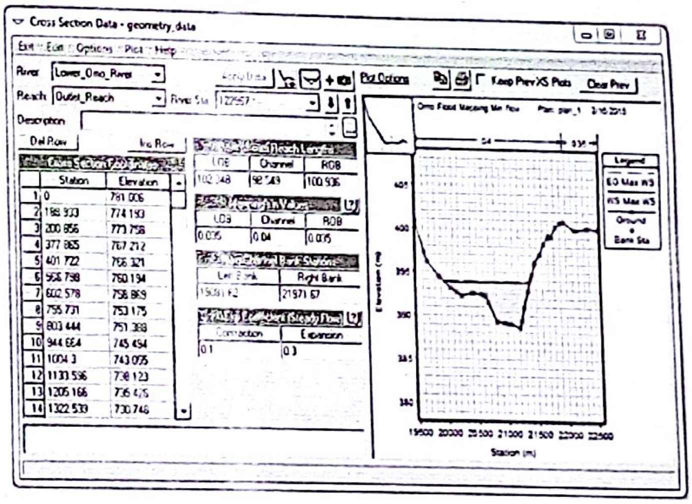


Figure 4-4: Cross section of the river at different stations at 122967 stations

The roughness value for Omo Ghibe River was determined by comparing the Chow(1988) standard photos with that of Omo Gibe River main channel and found to be between 0.035 and 0.04.

Unsteady flow solutions are selected in analysis for River training work and flood inundation studies. Discharge information is other boundary condition that required at each cross section in order to compute the water surface profile. Discharge data for flood of different flow condition was obtained from the HEC-HMS Model Output and used for analysis.

As shown in figure 4-5, the maximum and minimum flow of 21 year was selected from simulated flow. But the regulated flow was generated from Kuraz feasibility study monthly data

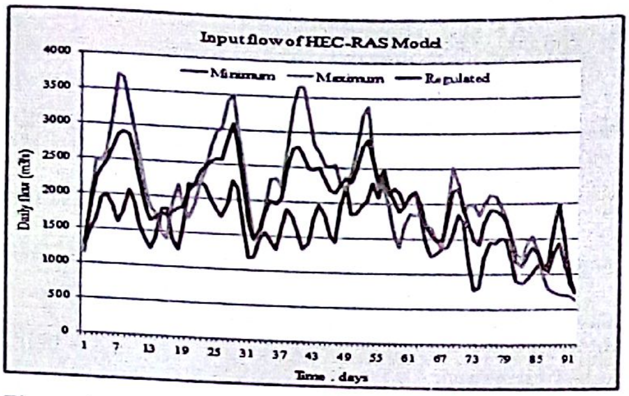


Figure 4-5: Flow hydrograph of maximum, minimum and regulated flow

The graph was drawn with the peak simulated discharge of these two minimum and maximum flow from 1989-2006 and regulated flow.

RESULTS AND DISCUSSION

HEC-HMS Hydrological Model Results

The rainfall-runoff modeling was conducted using HEC-HMS hydrological model through SCS unit Hydrograph method, Initial Abstraction, Lag time, CN, constant monthly base flow and Muskingum routing technique was used to simulate runoff for the sub-basin. The hydrological simulation is done particularly for Ghibe sub basin and Omo Ghibe basin above lower Omo Valley.

The HEC-HMS model is calibrated and validate for the observed period of twelve year (1995-2006) and the best-fit parameters sets are selected. For all gauging station daily and monthly data for the sub-basin from 1996-2002 was used for calibration and from 2003-2006 for validation and 1995 was used for warm up period.

Flow calibration was performed for a period of seven year from 1996-2002. As shown in figure 5-1 the calibration result proof that there is a good agreement between the simulated and observed monthly flows. The NSE was found to be 0.801, which is good correlation.

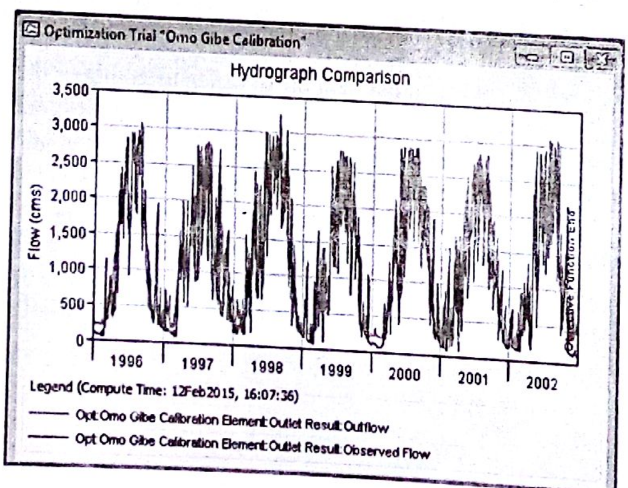


Figure 5-1: Hydrograph Comparison of Upper Lower Omo Calibration

Validation proves the performance of the model for simulated flows in periods different from the calibration periods. The NSE values was found to be 0 .84, which shows its good correlation with the observed flow.

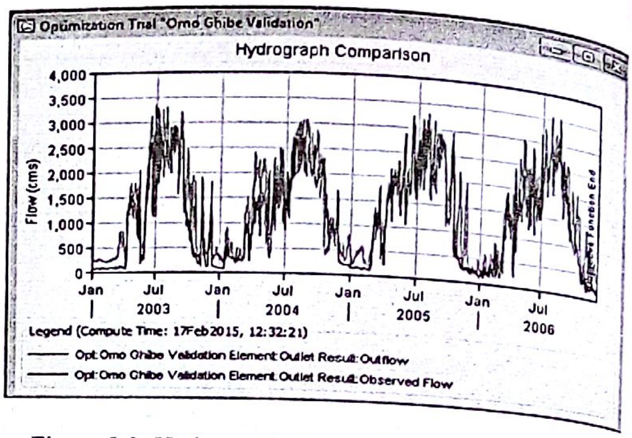
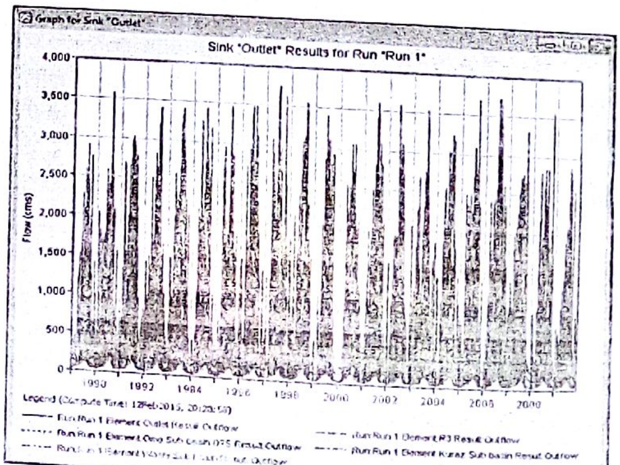


Figure 5-2: Hydrograph Comparison of Upper Lower Omo Validation

Table 5- 1: Upper lower Omo HEC-HMS optimization objective function

Measure	Simulated	Observed	Difference	% difference
Volume (MM)	45590.52	39410.63	6170.89	15.68
Peak Flow (M^3/S)	3252.2	2904.6	347.5	12.0
Time of Peak	20Aug1998 , 00:00	27Aug2000, 00:00		
Time of Centre of Mass	23Jul1999, 20:04	09Jul1999, 02:41		



Flood inundation mapping

Simulated water surface profiles for flood from 1989-2009 at selected cross sections where there is over breaching of riverbank was one of the outputs of HEC-RAS which was shown on figure 5.4.

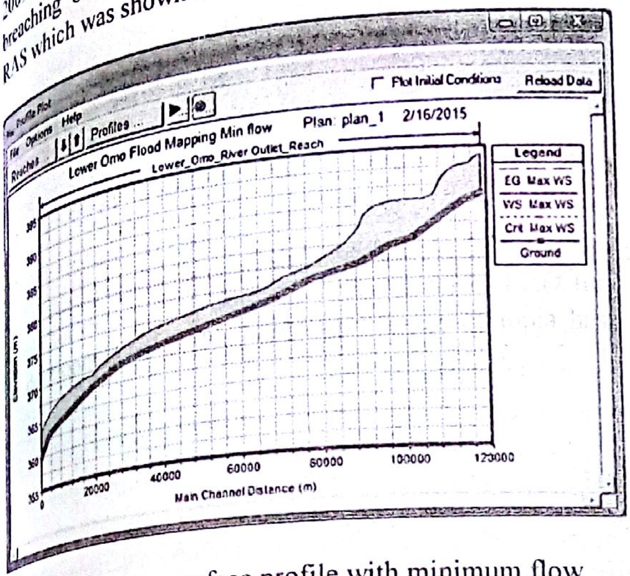


Figure 5- 4: water surface profile with minimum flow

Since the slope of lower Omo Valley was gentle and the peak flow on the valley was high there were flood inundation area. Most part of the right bank of the river is vulnerable to flooding by virtue of its low topography. The water surface profile of a single cross section with minimum, maximum and regulated flow of upstream basin shows that there was a significance difference between maximum and minimum flow. However, there was slight difference in inundation depth between minimum flow and regulated flow. The comparison of flood inundation area and flood depth was shown in table 5- 2.

Table 5- 2: Flood inundation Mapping area and depth

Flow	Woreda	Flood Inundation Area (km^2)	Depth (m)
Minimum Flow	Selamago	6.705	1.05
	Hammer	23.099	
	Dasenech	45.110	
	Gnangatom	32.080	
Maximum Flow	Selamago	12.0575	2.3
	Hammer	34.6485	
	Dasenech	87.165	
	Gnangatom	48.12	
Regulated Flow	Selamago	7.231	1.2
	Hammer	24.250	
	Dasenech	43.24	
	Gnangatom	36.05	

Existing Situation of Flood Recession Farming

In Lower Omo Ghibe sub basin flood recession agriculture has been practiced for a long time with maize and sorghum grown on the residual moisture after the flooding period.Annual flooding occurs in areas around Hamer, Dasanech, Selamago and Gnangatom woredas in the downstream reach of the Omo Gibe River. Lower Omo Valley inundates during July, August and September of which is suitable for crop production.

Figure 5- 5: Farmers direct flood to farm Gnangatom Woreda near Kangaten town

The timing and size of the flood will influence the production of the crops cultivated on the floodplain. Plenty of rainfall at the start of the rainy season in the upper catchment will cause the area to flood, and fertile sediment is deposited at the floodplain.

Flood recession farming with the future development

The lower Omo River has experienced a lot of flood problems in recent years but this will be regulated from now onwards due to the large hydropower dam of Gibe III HP. The development of cascaded reservoir facilities helped to reduce the peak and volume of runoff from a given catchment, which can reduce the frequency and extent of downstream flooding, soil erosion and sedimentation. This flow regulation at the upstream area may also be able to reduce the costs of large storm water drainage systems construction, as there are also no longer space for further deepening and widening of rivers and drainage systems. The design and construction of Ghibe III HP dam considers flood recession farming and releases around 760 m^3/s of discharge during peak flow.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

A hydrological, HEC-HMS, modeling is used to simulate the rainfall-runoff process. The HEC-HMS program was selected for this particular study due to its versatility, capability for runoff generation, automatic parameter optimization and its connection with GIS through HEC -GeoHMS. The HEC-HMS hydrological model which is calibrated and validated in daily time step, simulate the observed discharge in reasonably well manner with the model performance criteria of Nash and Sutcliffe value on average NSE resulted from 0.801 to 0.867 in Ghibe sub basin and upper lower Omo sub basin gauge stations for calibration and 0.84 to 0.88 for validation on monthly scale.

The conditions found in the floodplains in the lower Omo basin with minimum flow with in twenty one years were compared with maximum annual flow where flood recession agriculture is practiced. Thus GIS and HEC-RAS hydraulic model showed that the maximum depth of flood inundation with minimum flow was (1.05 m), regulated flow was (1.2 m) and with maximum flow (2.3 m) and the area covers four woredas i.e. Selamago, Hamer, Gnangatom and Daenech. This shows that the flood depth with minimum and regulated flow was approximately the same.

The total existing flood inundation area over twenty one years (1989-2009) with minimum flow in 1989 was (107 Km^2) and maximum flow in 2006 was (182 Km^2). But this flow will be regulated in the future due to cascaded reservoir and the future flood inundation area with regulated flow will be (111 Km^2). The overview of flood inundation area and flood recession farming practices has proved that farmers have developed methods to deal with the changing conditions independently.

Recommendations

Generally from this study the following points are recommended;

In order to improve the input data for HEC - HMS model application and as a follow research suggest that the comprehensive meteorological data and hydrological data should be installed in Lower Omo sub basin because of large part of Omo Gibe basin is ungauged catchment.

More detailed and more specific hydrological survey should be studied and documented in the lower Omo Ghibe sub- basin which can help to get a better understanding of the systems and their influence on flood recession agriculture, electronical pre- flood warming instruments should be installed.

In future development of cascaded reservoir and irrigation project the conventional

irrigation methods for rural community should be studied and implemented.

REFERENCES

Abebe, D. (2010), Use of flash floods for optimizing productivity in irrigation case of Boru Dodota spate irrigation scheme, Ethiopia, MSc thesis: UNESCO_IHE

Abebe M, (2011), Flood Recession Farming: Case Study from the Upper Awash Catchment, Ethiopia.

Alemayehu, T. (2008), Ethiopia spate irrigation country profile: Addis Ababa, Oromia Water Works Supervision and Design Enterprise.

Allen, R. G., Pereira, L. S., Raes, D., Smith, M. (1998). Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No 56. Rome, Italy: Food and Agriculture Organization of the United Nations.

Barnes, H.H., Jr. (1967). Roughness characteristics of natural channels.U.S. Geological Survey Water-Supply Paper 1849.

Belay Zegeye, (2008), GIS Based Hydrological Modeling for Woldiya Water Shed and Hydraulic Modeling of Upper Shelle Reach. Arba Minch University Master Thesis.

Bergstrom - and Graham, L.P.S. (1998). On the Scale Problem in Hydrological Modeling. Journal of Hydrology, 211(1-4):253-265.

CFCAS. (2004). "Assessment of Water Resources Risk and Vulnerability to Changing Climatic" Project Report IV, Calibration, Verification, and Sensitivity Analysis of the HEC-HMS : 23.

Chow,V.T., Mays Maidment., & L.W.D.R. (1988). Applied Hydrology .McGraw-Hill publishing company, New York.

David M., Eric T., and FranciscoO. (1998).GIS for flood plain mapping indesign of highway drainage faci li ties, research report 1738-4, Universi ty of Texas at Austin.

Demelash Wondimagegnehu, (2011), Evaluation of Climate Change Impact on Blue Nile Basin Cascade Reservoir operation(Case Study of proposed reservoirs on the Main Blue Nile River Basin, Ethiopia), Arba Minch University Master Thesis.

FAO,(1992), Irrigation water management training manual-7: FAO land and water development division, October 1992: Rome, Italia

FAO, (2010), Guideline for spate irrigation: irrigation and drainage paper, Rome, Italy

FAO, (2002), Major Soils of the World. Land & Water Digital Media Series. FAO Soil Buletin.No (19), Rome. Itally.

FAO, (1995), Digital Soil Map of the World and Derived Soil Properties (CDROM) Food and Agriculture Organization of the United Nations, FAO

Girma,Y.(2008). Hydrological Response of a Catchment to Climate Change, Case Study on Upper Beles Sub- Basin, Upper Blue Nile, Ethiopia. MSc thesis done for the partial fulfillment of the requirements of the Master of Science degree at UNESCO-IHE Institute for Water Education.

Haile, A. (2007), A tradition in transition, water management reforms and indigenous spate irrigation systems in Eritrea Leiden: published (Taylor and Francis/ Balkema). Ph. D. thesis. Wageningen University

HR.Wallingford/Meta Meta, (2011), Spate Irrigation in Ethiopia: http://www.spate- irrigation.org/librar/ ethiopia.htm

Juraj, M., & Cunderlik. (2003). Hydrologic model selection for the CFCAS project: Assessment of water resources risk and vulnerability to changing climatic conditions.

Moriasi,N.D., J. G. Arnold,W.M., Van Liew,LR.,Bingner,D.R., & Veithand T. L.Harmel. (2007). Model Evaluation Guidelines For Systematic Quantification of Accuracy in Watershed Simulations. American Society of Agricultural and Biological Engineers, Vol. 50 (3): 885–900.

Nash ,J.V.Sutcliffe J.E. (1970). "River flow forcasting through conceptual models, part one." A discussion of principles. J.Hydrology 10(28) (1970): 282-290.

OCHA Situation Report No. 6, 2006, floods: Ethiopia

Richard Woodroofe & associates, (1996), Omo-Gibe River basin Integrated Development Master Plan Study Final Report. Vol. III,VI Water resources Surveys and Inventories, ministry of Water Resources, Addis Ababa.

Soil Conservation Service, (1986). Urban hydrology for small watersheds Technical Release 55. USDA, Springfield, VA.

Spate irrigation network, (2011), Spate irrigation in the horn of Africa: status and potential

Steenbergen, F. (1997). Institutional changes in local water management: cases from Beluchistain. Utrecht University, NL

Steenbergen, F., Olaf V., Sanne, A. and Abraham, H. (2011), Spate Irrigation, Livelihood Improvement and Adaptation to Climate Variability and Change

Tate, E.C, et al ,(1999), Floodplain Mapping Using HEC-RAS and ArcView GIS, M.S.E. Thesis, University of Texas at Austin, CRWROnline Report 99-1.

UNDP and FAO, (1987), Spate irrigation, proceeding of the sub regional expert consultation on wadi development for agriculture in the natural Yemen

USACE. (2001). "Hydrologic Modeling System HEC-HMS, Users Manual." US Army Corps of Engineers.

USACE. (2003). US army corps of Engineers. "Geospatial Hydrologic Modeling Extension HEC-GeoHMS, User"s Manual US Army Corps."

Hydrologic Engineering Center US army corps of Engineers.

USACE. (2008). Hydrological Modeling system (HEC-HMS) User's Manual , US Army corps of Engineers.

U.S. Army Corps of Engineers, (2003). Geospatial Hydrologic Modelling Extension HEC-GeoHMS. User's Manual. US Army Corps of Engineers, Hydrologic Engineering Center.

Ven Te Chow, (1964). Hand Book of Applied Hydrology, A Compendium of Water Resources Technology, Mc Grew – Hi ll Book Company, NY, USA.

WeizheA., (2007). The study of GIS-Based Hydrological model in highway environmental assessment, Doctor of Philosophy paper, University of Pittsburgh.

WWDSE (2013), Kuraz Sugar Development Project Sectoral Study Reports Climatology and Hydrology Study Report

Farmer's Perception about the Performance of Koga Irrigation Scheme and Impact of Climate Change

Beza Berhanu (M.Sc) and Alemseged Tamiru Haile (Ph.D.)

[1]*International Water Management Institute, P. O. Box 5689, Addis Ababa, Ethiopia*

Corresponding author email: bezabbberhanu@gmail.com

Abstract

Ongoing and planned water resources projects across Ethiopia are expected to alleviate impact of climate variability and change on the agricultural sector. In this study we assessed the current performance of the Koga irrigation project as well as its vulnerability to climate change. Koga irrigation project is the first to be operational in the Lake Tana sub-basin of the Upper Blue Nile basin, and therefore serves as a learning case for the upcoming projects. Data were gathered through a household questionnaire survey of 90 beneficiary farmers of the Koga irrigation project. The data were analyzed using the Statistical Package for the Social Sciences (SPSS) software. Farmers stated the benefits of the irrigation project as: increased productions and profits by multiple cropping, increased savings, increased children's school enrollment and in general better livelihoods. However, 57% of the respondents are not totally satisfied with the current water allocation of the scheme. For more than sixty percent of the respondents the amount of the allocated irrigation water is less than the actual water demand. About 70% of the farmers perceive the irrigation interval as too long to timely satisfy the existing crops water demand. We also evaluated farmer's perception about climate change and the scheme's vulnerability. Hail was cited as one of the major climate stress in the region by 60% of respondent. Farmers felt a change in rainfall pattern in the past 20 years (70%) mostly with an early onset of rainfall (80%) and increased rainfall variability (30%). Slightly less than half of the farmers believe that temperature has increased over the past 20 years. About 58 % of the farmers anticipate future water shortage in the Koga scheme as a result of changes in rainfall and temperature combined with sedimentation. Overall, we were able to recognize the benefits and existing challenges of the irrigation scheme. The Koga irrigation scheme is a well-functioning irrigation system with some existing and forthcoming challenges. Therefore, measures that will avoid water allocation difficulties or that will improve the farmer's adaptation capacity to water shortage need to

Introduction

Background

There is undeniable scientific evidence about the increasing concentration of greenhouse gases in the atmosphere and its visible impact on the global climate system (IPCC, 2013). Over the period 1880 to 2012, the globally averaged combined land and ocean surface temperature data showed a warming of 0.85 °C (IPCC, 2013). Mean temperature over Ethiopia has increased by 1.3°C between 1960 and 2006 at a rate of 0.28°C per decade (McSweeney et al., 2010). The corresponding precipitation trend during the last 3-6 decades was not very clear although its change is often implicated as a source of droughts and floods in eastern Africa countries including Ethiopia (Niang et al., 2014). The IPCC Fifth Assessment Report (AR5), states that GCM projections of annual precipitation in the Upper Blue Nile basin (UBN) do not agree on the direction of precipitation change (Niang et al., 2014) while the average temperature is projected to increase by 2 to 5°C by the end of this century (Elshamy et al., 2009). Such changes in rainfall and temperature are, therefore, expected to affect potential evapotranspiration (Elshamy et al., 2009), crop water requirement (McKenney and Rosenberg, 1993) and socio-economic development (Fisher et al., 2007) in the region.

In order to adapt to the observed and projected climate variability and changes, farmers in UBN have been taking various measures including water harvesting, trees planting, early and late crop planting, terracing, crop diversification and others (Deressa et al., 2009; Salvatore et al., 2012; Tessema et al., 2013). To support such local initiatives, the government of Ethiopia is also responding to the changing climate in the region. For instance, the five large scale irrigation schemes[1], which are commissioned or under construction in the Lake Tana sub-basin, are among those bold government initiatives that are aiming at improving food security while reducing the vulnerability of local communities in the region. Koga irrigation scheme is the first large scale irrigation project to be operational in the Lake Tana sub-basin. Its construction has been completed and become operational since 2009.

However, the current water demand and supply sides of the Koga irrigation scheme were estimated under the assumption of a stationary climate by undermining projected increased temperature and reduced stream flow for Lake Tana sub-basin (Setegn et al., 2011; Abdo et al., 2009). Recent study by Berhanu and Haile (2015) also predicted a likely increase in future water requirement of Koga irrigation scheme under all representative concentration pathway scenarios (RCPs) to question the reliability of future irrigation water demand and delivery of this scheme.

In addition to the impact of climate change on the supply and demand sides of irrigation, farmers' perception about the impact of climate change on irrigated agriculture and possible options to deal with such impacts are important to ensure the sustainability of irrigation schemes (Koontanakulvong et al., 2014). This is because perception plays a great role in farmers' level of response to climatic change, choice of adaptation measures and how they will be affected by such changes.

This study is focused on the case of Koga as an operational irrigation scheme to assess the perception of the benefiting farmers' about the impact of climate variability and change on irrigated agriculture (water demand and supply). The objectives are to understand farmers' perception about the existing water allocation in the irrigation scheme and evaluate farmer's perception about climate change and its impact on irrigation water demand and supply. Since irrigated agriculture will continue to expand to feed the growing population in Ethiopia, the study will generate valuable information to make the upcoming irrigation projects more resilient to climate change.

Study Area

General characteristics of the study area

The Koga Dam is built on the Koga River at 11°24′31″ North and 37°9′39″ East coordinates with an elevation stretching from 1800 m above sea level (downstream area) to 3000 m above sea level (upstream area). It is situated in the Amhara regional state of Ethiopia at a distance of about 35 km south of Bahir Dar. Mean daily temperature of Koga watershed was 19 degrees Celsius from 1960-2003 and it received 1560 mm of precipitation annually on average during that same period. High rates of erosion are stimulated by high river flows that occur during the rainy period as a result of precipitation and runoff (Reynolds, 2013). Almost 87% of the area consists of silty clay soils which are suitable for irrigation (Eriksson, 2013). The major land use/land cover features of the watershed before the start of the irrigation project were cultivated land,

settlement, scrub-wetland, bush land, few remnants of natural forest trees and also some planted Eucalyptus trees around settlements (Gebrehiwot et al., 2010).

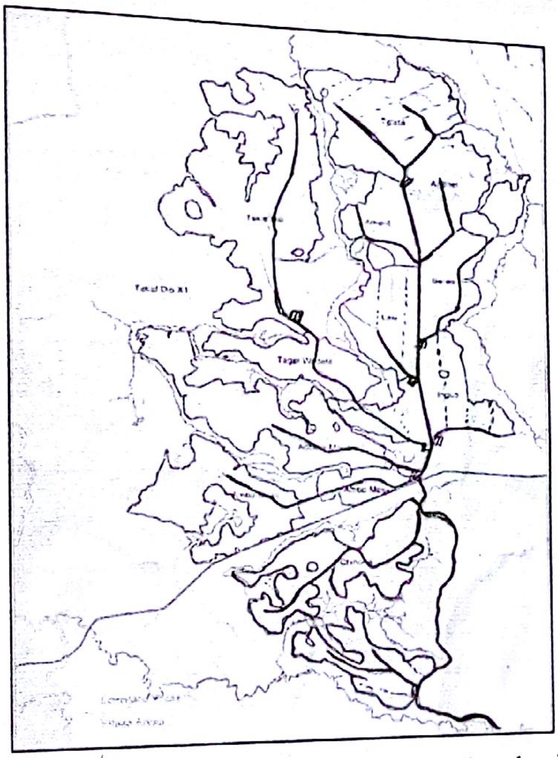
Koga irrigation project

Koga irrigation scheme is the first of the six large scale reservoirs that the Ethiopian government planned to construct in Lake Tana sub-basin with an aim of ensuring food security in the region and beyond. The construction work of Koga irrigation project was started in November 2004 and completed in May 2011. Parts of the scheme were operational since the dry season of 2009/2010 though the construction of some tertiary or quaternary canals was not fully completed. The Koga reservoir covers 1750 ha surface area with a storage capacity of 83.1 million cubic meters. The target irrigated area in the design report is 7004 ha with possible addition of 196 ha if water saving technologies are applied. However, the actual irrigated area during the dry season of 2013/2014 was 5830 ha covering 10,356 farm households (Figure 1).

Figure 1: Koga irrigation scheme

Methods

Structured interview



Quantitative and qualitative data were collected using structured questionnaires.

The questionnaire consists of 86 open and closed questions grouped in to five main sections: (i) (iii) exposure and sensitivity to climate change impacts; (iv) current

irrigated farming; (ii) farmers' satisfaction;

coping mechanisms; (v) anticipated exposure and adaptive capacity to climate change. The survey lasted for about 30 to 40 minutes for each respondent. The questionnaire was prepared in English language but later translated in to the local language (i.e., Amharic). The accuracy of the Amharic translation was assessed by a local expert who did not participate in the preparation of the questionnaire.

In order to assess the level of understanding and difficulties associated with the interpretation of the questionnaires, the research team has trained three enumerators and helped them to conduct a pre-test survey. Once they were qualified to conduct an independent interview, a total of 93 randomly sampled farmers were surveyed from the 12 irrigation units of the Koga irrigation scheme.

Statistical analysis

The quantitative data collected through the structured questionnaire were first checked for consistency and then digitized. The data were then analyzed using the Statistical Package for Social Sciences (SPSS). Descriptive statistic (min., max., mean, percentage and standard deviation) was used to analyze the collected data.

Results

Socio-economic profile of the respondents

Farmers benefiting from the Koga irrigation scheme have an average age of 40 years (Table 1). Crop cultivation is the major livelihood strategy and source of income to these farmers. However, about 87% of the respondents are also involved in more than one income generating activities mainly in livestock rearing. Average land holding is 1.2 ha with a maximum of 4 ha. Most farmers with a large landholding stated that they cultivate only part of their land in each production season due to lack of labor and limited financial capacity to purchase agricultural inputs. Irrigation farming is a new activity in the area and almost all the surveyed farmers did not have any irrigation experience before the start of the Koga irrigation scheme in 2009.

Table 1: Socio-economic profile of the respondents

Sex	Female (%)	25
	Male (%)	75
Age	Min	22
	Max	70
	Mean	40.75
	St. Dev.	11
Irrigation farming experience before the Koga project	Yes (%)	3
	No (%)	97
Source of income	Crop cultivation (%)	100
	Livestock (%)	87
	Petty trade (%)	5
	Other (%)	3
Number of activities generating incomes	One (%)	13
	Two (%)	80
	Three (%)	7
Landholding	Min	0.25
	Max	4
	Mean	1.18
	St.Dev.	0.77

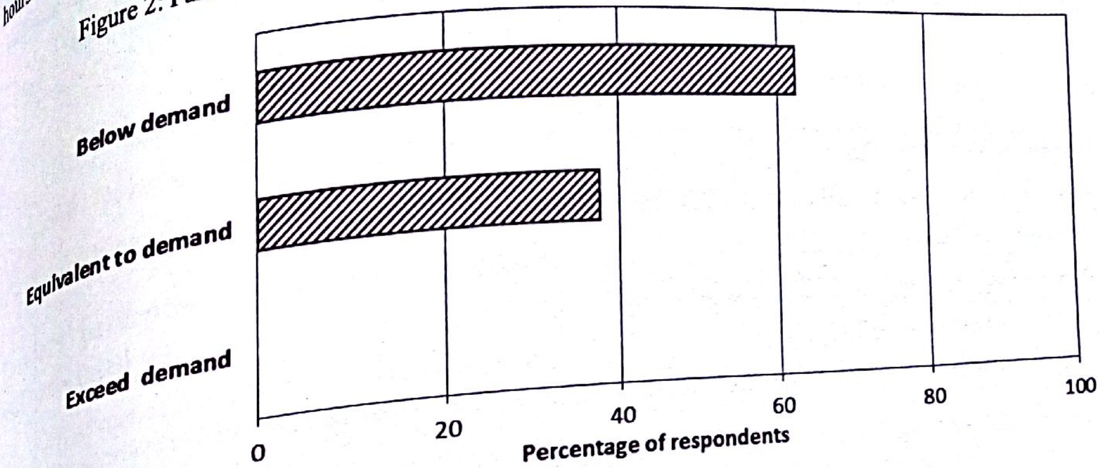
Farmer's perception about the existing water allocation of the scheme

Farmers stated that the irrigation scheme has brought multiple benefits to them. While they used to cultivate only once a year by relying on the rainy season, they are now cultivating at least twice a year (after the commissioning of the scheme). As a result of multiple cropping, farmers are able to improve their crop yield, income and livelihood (e.g. improved nutrition, better houses and improved living standards). The improvement of income from their irrigated agricultural activities has helped them to save some money in a bank, which was not common in the area before the start of the project. As a result, children school enrollment has drastically increased since farmers are able to incur the cost of sending their kids to school. This has caused labor shortage in some households as kids were the once who helped them in farm activities.

Despite the multiple benefits of the irrigation scheme, about 57% of the respondents are not satisfied with the current water allocation. Their dissatisfaction is mainly related to the irrigation water amount and interval.

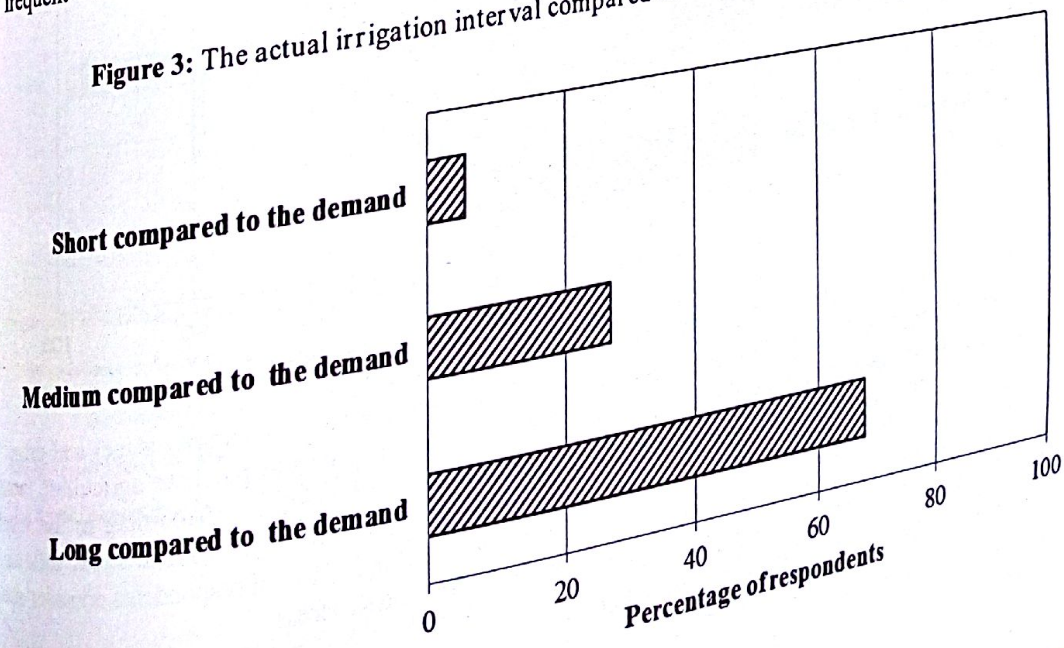
The amount of the allocated water for >60% of the respondents is less than their actual water demand (Figure 2) as the allocation did not take into account the type and stage of crop. The current discharging rate at the Koga irrigation scheme is based on fixed flow (30 l/s for 12 hours to irrigate 2ha), which is levied during the design phase of the project. The discrepancy between water demand and supply has induced impact on the performance of their crops. According to the respondents, water shortage is causing decline in crop yield and increase in pest infestations in the area.

Figure 2: Farmer's perception about amount of allocated water compared to the irrigation demand



About 70% of the farmers stated that the current irrigation interval is too long to timely satisfy the water demand of existing crops (Figure 3). The average irrigation interval is 11 days but depending on the location of the irrigation unit it can go as short as 5 days and as long as 30 days. As a result, farmers are forced to make adjustments on their crop selection. They opted to less water demanding crops (such as cereals) rather than planting more profitable crops with frequent water demand (e.g. vegetables). Despite their dissatisfaction on the irrigation interval, majority of the respondents (~85%) consider the current water rotation as reliable as they received water on due date. However, farmers' complained that they are not benefiting from this irrigation scheme during the rainy season for instance in times of early rainfall offsets or extended dry spells although the reservoir was designed and build to store sufficient water for both seasons.

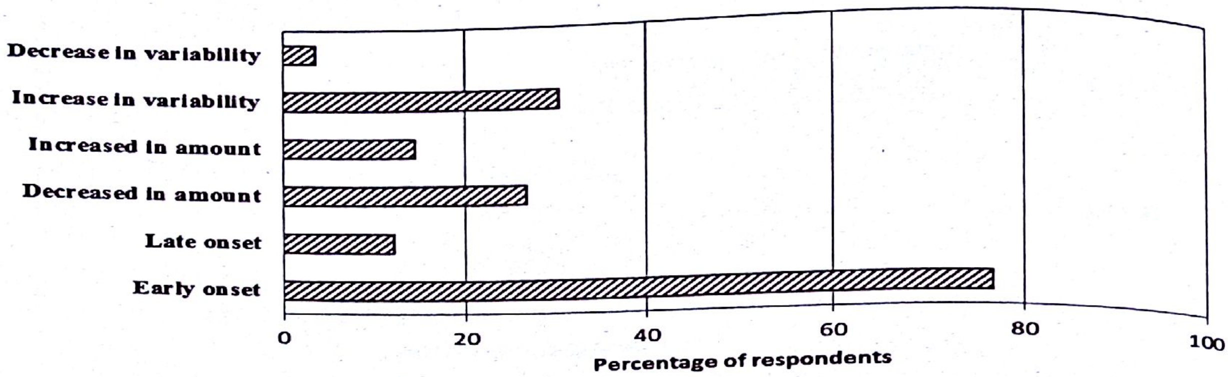
Figure 3: The actual irrigation interval compared to the required irrigation interval



Farmer's perception on historical climate variability and change

We assessed farmers' perception on historical climate variability and change with the assumption that farmers' perception towards these changes could affect their responses and provides useful inputs to understand the existing adaptive capacity. With regard to historical rainfall patterns, 70% of the respondents recognized changes in rainfall pattern over the past 20 years (Figure 4). Of these, almost 80% of them stated that the current onset of rainfall is earlier than before. Appreciable percentage of the respondents (30.5%) had also noticed increased rainfall variability over the years. The number of respondents who reported a decrement in rainfall amount is greater than those who reported an increment. Most of the respondents generally said that rainfall has become less predictable and posed difficulties to schedule their agricultural activities based on their existing indigenous knowledge.

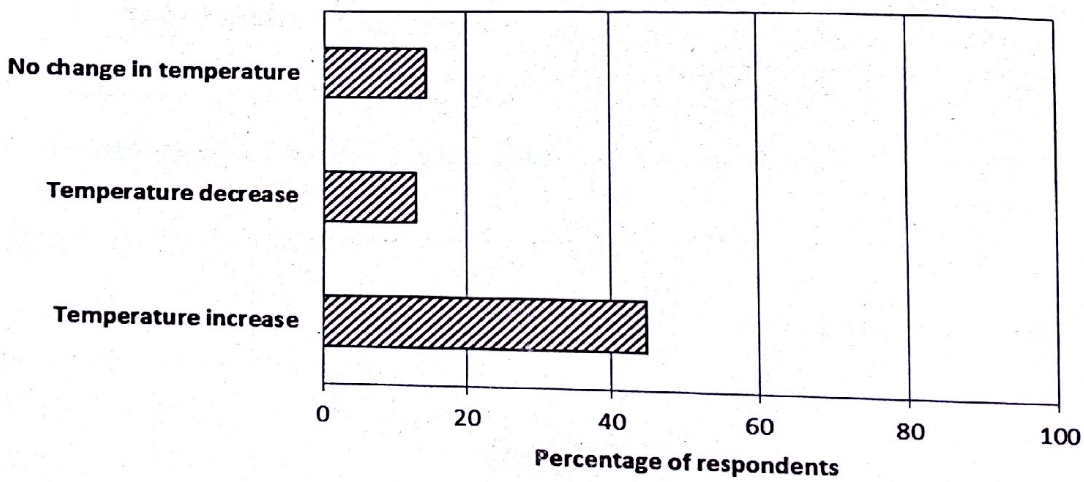
Figure 4: Farmers' perception of changes in rainfall in the last 20 years (% respondents)



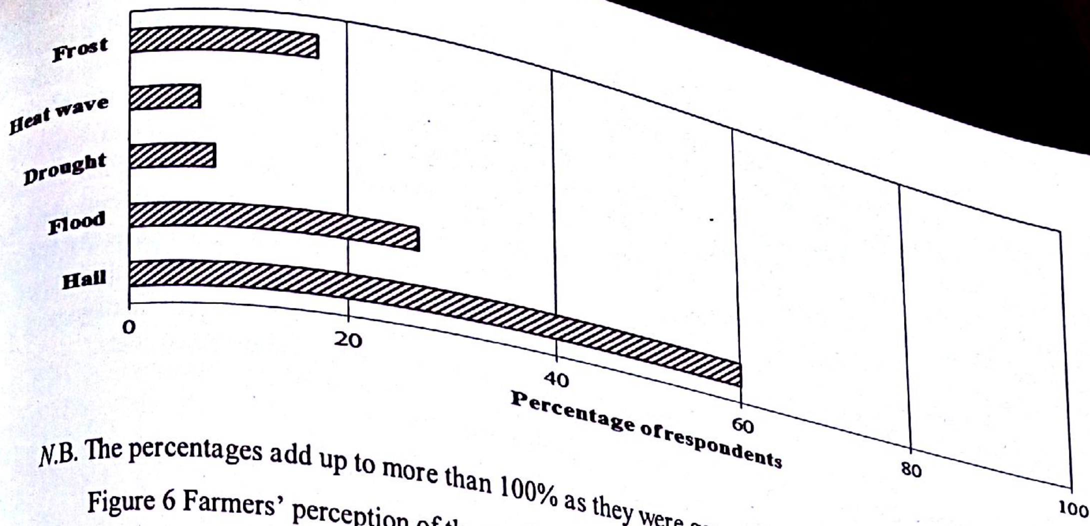
N.B. The percentages add up to more than 100% because they were generated from multiple answer questions.

Slightly less than half of the farmers believe that temperature has increased over the past 20 years (Figure 5). A rise in temperature is explained by an increase in crop water requirement, an increase in crop diseases and pest proliferation. However, about 13% of the respondents observed a decrease in temperature over the past 20 years while 14% did not recognize any change.

Figure 5: Farmer's perception of changes in temperature in the last 20 years



Farmers' perception about the major climate stresses in the last 20 years was also evaluated and 60% of the respondents considered hail as one of the major climate stresses in the study area (Figure 6). The unexpected hail occurrence may, sometimes, destroy the standing crops and left farmers with empty hands. For example, in 2014, most of the maize farms in Ambo Mesk irrigation unit were destroyed by hail (at maturity stage) and greatly affected farmers' capacity to purchase agriculture inputs in the coming irrigation season. According to the respondents, flood is the next major climate stress followed by frost. Only less than 10% of respondents consider drought as the major climate stress.



N.B. The percentages add up to more than 100% as they were generated from multiple answer questions.

Figure 6 Farmers' perception of the major climate stresses in the last 20 years (% respondents)

Farmers' perception on future climate change and associated impacts

Fifty eight percent of the respondents anticipate that irrigation water shortage in the future will affect their agricultural activities. However, most of them (54%) do not anticipate water shortage in the near future (within 5 years). Among those farmers who anticipate shortage, 58% and 35% of them fear that water shortage will occur in the middle (5-10 years) and long term (>10 years) respectively (Figure 7). The rationale behind their perception is that the future irrigation water shortage will probably occur due to reservoir sedimentation and an increase of irrigation water use than changes in climate variables (Figure 8). Farmer's fear of increased water use in the future may be linked to increased awareness of the benefit of irrigated farming which may lead to very intensive irrigated agriculture activities. On the question "who will be more affected by future climate change", nine out of ten respondents identified farmers at the tail reach of the scheme to be more vulnerable to climate change. They believe that these farmers are more prone to water shortage because they are located far away from the main reservoir and are susceptible to increased water loss along the canal. They also believed that poor water management does aggravate this situation.

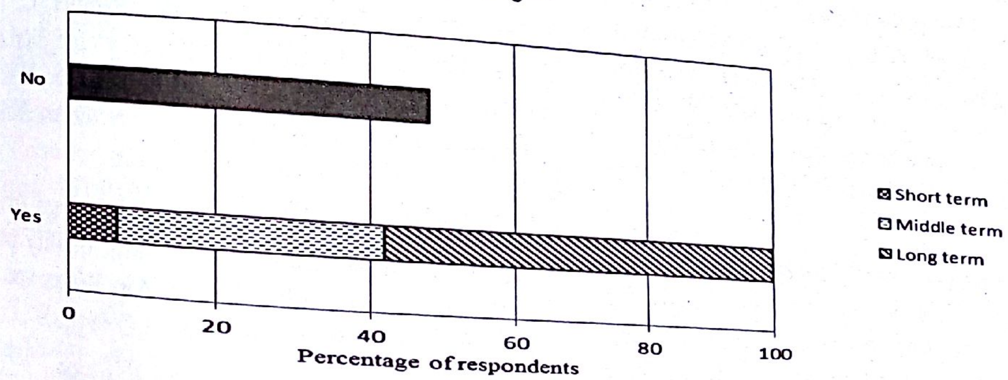
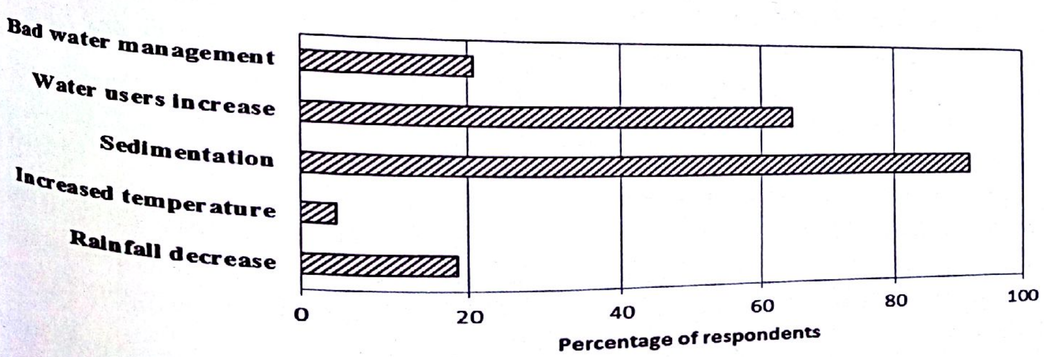


Fig-

of

ure 7: Percentage re-



spondents who anticipate irrigation water shortage in the future

Climatic factors do not seem to be farmers' biggest fears in Koga as they stated that temperature and rainfall variation will have limited impact in terms of water shortage. This is mainly due to their belief that they cannot do much with regard to climatic variables as it depends only on the "will of God" and they preferred to concentrate on factors that can only be managed by them. Comparatively, farmers are more concerned about the effect of decreased rainfall on future water shortage (19%) than increased temperature (4%).

Discussion and conclusion

As farmers are the direct beneficiaries of the Koga irrigation scheme, it is important to consider their perceptions about the existing water allocation and water shortage phenomena. This study found that most beneficiaries are not totally satisfied by the existing allocation of the irrigation water and are concerned about the amount and interval of the supplied irrigation water. Currently, farmers are not able to plant profitable crops (like vegetables) as their water demand is larger or more frequent than the amount and frequency of water delivered by the scheme. The initial fixed flow rate of 30 l/s for a period of 12 hours is basically planned to irrigate 2 ha without considering the crop type or stage of crop development. Hence, the existing water allocation practice should be revised so that farmers' can shift from cereal cultivation to profitable crops like vegetables.

Farmers perceive hail as the major climate stress in Koga scheme. Hail frequently destroys standing crops. However, hail has not been given due attention in previous studies (e.g. Deressa et al., 2009; and Deressa et al., 2011). Therefore, the concerned bodies need to thoroughly consider this climate stress and work to build viable shielding measures.

In this study, more than half of the respondents noticed a rise in temperature in/around their area. Surprisingly, the majority of the respondents believe that changes in climatic variables (such as temperature and rainfall) will have less impact on the volume of water stored in the reservoir. Rather, sedimentation is their number one reason responsible for a significantly reduction in the actual amount of water stored in the reservoir. This indicates that farmers have little understanding about the link between climate variables and the volume of water in the reservoir. Apart from sedimentation, farmers in Koga irrigation scheme linked future water shortage to an increased water use and bad water management that warrant improvement on the existing water management system to avoid/reduce probable cause of water loss.

The Koga irrigation scheme is a well-functioning irrigation system with some existing and forthcoming challenges with regard to its water allocation and its vulnerability to climate change. However, for better crop harvest, the fixed flow rate and long irrigation interval should be adjusted in accordance to the crop-water requirement demand. The irrigation project management should consider releasing reservoir water as supplemental irrigation in the rainy season particularly during early rainfall offsets, extended dry spell. This is needed to maximize the benefit from this big investment. Overall, measures that will avoid water allocation difficulties or that will improve the farmer's adaptation capacity to water shortage need to be implemented based on evidence-based study.

Reference

Abdo, K. S., Fiseha, B. M., Rientjes, T. H. M., Gieske, A. S. M. and Haile, A. T. (2009) 'Assessment of climate change impacts on the hydrology of Gilgel Abay catchment in Lake Tana basin, Ethiopia', *Hydrological Processes*, Vol. 23 No. 26, pp.3661–3669.

Berhanu B. and Haile A.T. (2015) 'Evaluating climate change impact on water demand of irrigation schemes in the Lake Tana basin using newly developed climate change scenario'. Proceedings of the 14th Symposium on Sustainable Water Resources Development, Arba Minch University Arba Minch, Ethiopia, pp.29-30.

Deressa T. T., Hassan R. M., Ringler C., Alemu T. and Yesuf M. (2009) 'Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia', *Global Environmental Change*, Vol. 19 No.2, pp.248–255.

Deressa T. T., Hassan R. M. and Ringler C. (2011) 'Climate change and agriculture paper: Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia' *Journal of Agricultural Science*, Vol. 149, pp.23–31.

Eriksson S. (2013) 'Water quality in the Koga Irrigation Project, Ethiopia: A snapshot of general quality parameters'. Department of Earth Sciences, Air, Water and Landscape Science, Uppsala University.

Elshamy, M. E., Seierstad I. A. and Sorteberg A. (2009) 'Impacts of climate change on Blue Nile flows using bias-corrected GCM scenarios' *Hydrology and Earth System Sciences*, Vol. 13, pp. 551-565.

Gebrehiwot, S. G., Taye, A. and Bishop, K. (2010) 'Forest Cover and Stream Flow in a Head water of the Blue Nile: Complementing Observational Data Analysis with Community Perception', *Royal Swedish Acedemy of Sciences*, Vol. 39 No.4, pp.284-294.

Haile, A.T., Kusters, K. and Wagesho, N. (2013) 'Loss and damage from flooding in the Gambela region, Ethiopia', *International Journal of Global Warming*, Vol. 5, No. 4, pp.483–497.

IPCC (2013) *Summary for Policymakers. In: Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Koontanakulvong, S., Chaowiwat, W. and Miyazato, T. (2014) 'Climate change's impact on irrigation system and farmers' response: a case study of the Plaichumpol Irrigation Project, Phitsanulok Province, Thailand' *Paddy and Water Environment*, Vol 12 No. 2, pp.241–254.

McKenney, M.S. and Rosenberg, N.J. (1993) 'Sensitivity of some potential evapotranspiration estimation methods to climate change', *Agriculture and Forest Meteorology*, Vol. 64 No. 1-2, pp.81-110.

McSweeney, C., New, M., Lizcano, G. and Lu, X. (2010) 'The UNDP Climate Change Country Profiles Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Country', *Bulletin of the American Meteorological Society*, Vol. 91 No.2, pp.157-166.

Nhemachena, C. and Hassan, R. (2007) *Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa*. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute. Washington DC, USA.

Niang, I., Ruppel O.C., Abdrabo M.A., Essel A., Lennard C., Padgham J. and Urquhart P. (2014) 'Africa. In: Climate Change: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects'. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp.1199-1265.

Reynolds B. (2013) 'Variability and change in Koga reservoir volume, Blue Nile, Ethiopia., *Examensarbete vid Institutionne för geovetenskaper*, ISSN I650-6553 Nr 261.

Salvatore D.F., Köhlin G. and Yesuf M. (2012) 'Strategies to Adapt to Climate Change and Farm Productivity in the Nile basin of Ethiopia', *Climate Change Economics*, Vol. 3 No.2.

Setegn, S.G., Rayner D., Melesse A.M., Dargahi B., Srinivasan R. and Wörman A. (2011) 'Climate Change Impact on Agricultural Water Resources Variability in the Northern Highlands of Ethiopia', *Nile River Basin*, Springer, pp.241-265.

Tessema Y.A, Aweke C.S. and Endris G.S. (2013) 'Understanding the process of adaptation to climate change by small-holder farmers: the case of east Hararghe Zone, Ethiopia', *Agricultural and Food Economics*, Vol.1 No.13.

Notes

Ribb, Megech, Gilgel-Abbay, Jema and Gumara irrigation projects are currently under construction within the Lake Tana sub-basin

Impact of Land Use Land Cover Change on Stream Flow and Sediment Yield: A Case Study of Gilgel Abay Watershed, Lake Tana Sub-Basin, Ethiopia

Tesfa Gebrie[1] *and Bogale Gebremariam*[2]

[1]*Amhara Water Resources Development Bureau, tesfag23@gmail.com, P.O.Box. 88, +251918310029*

[2]*Arba Minch Institute of Technology, bgmariam@gmail.com , P.O.Box. 21, +251932610018*

Abstract

Gilgel Abay watershed is densely populated causing various effects on resource bases like deforestation, expansion of residential area, and agricultural land. The watershed is also facing high erosion by the effects of intense rainfall of the watershed, which aggravates the land cover change of the watershed. This study was designed at application of SWAT for the assessment of impacts of land use land cover change and best sediment management practices that are related to hydrology/stream flow and sediment yield of the watershed. The land use land cover change analyses were performed using ERDAS Imagine 2014 that was used for further analysis of SWAT. Land use land cover changes for three different years of 1986, 2000 and 2011 land use scenarios with different management practices were used for estimation of stream flow and sediment yield. During the study period most parts of the grassland and shrub land were changed to cultivated land. An increase of cultivated land by 33.79% over 25 years period (1986 – 2011) resulted an increase of stream flow and sediment yield by 5.87m^3/s and 62.78t/km^2 respectively. The Nash Sutcliff efficiency, coefficient of determination (R^2) and RSR were used for evaluating the model performance. Spatial variability of sediment were also done using the validated sediment yield results of 2011 land use on Arc GIS. Hence, for the critical sub- watersheds the design and development of best management practices were performed. Three BMPs (best sediment management scenarios) S1 (filter strip), S2 (stone bund) and S3 (reforestation) were considered in this study. The results has showed a decrease of sedimentation by 24.73%, 21.36% and 36.18% sediment yield reductions implementing S1, S2 and S3 respectively. Therefore practicing S3 for Gilgel Abay watershed should be implemented and encouraged for efficient sediment reductions.

Key words: Gilgel Abay watershed, land use change, stream flow, sediment yield, SWAT, ERDAS Imagine, BMP

Introduction

Land and water resources degradation are the major problems in the Ethiopian highlands. Poor land use practices and improper management systems have played a significant role in causing high soil erosion rates, sediment transport and loss of agricultural nutrients [1]. Gilgel Abay watershed, which is one of the sub watersheds of Lake Tana basin, is densely populated with an annual growth rate of 2.3 % [2]. This causes various effects on resource bases like deforestation, expansion of residential area and agricultural land. The watershed is also facing high erosion by the effects of intense rainfall of the watershed which aggravates the land cover change of the watershed. This continuous change in land cover has influenced the water balance of the watershed by changing the magnitude and pattern of the components of stream flow that are surface runoff and ground water flow, which results increasing the extent of water management problem. Therefore, The main objective of this study was to evaluate the amount and pattern of stream flow and sediment yield under different land use/cover changes of the catchment and assess different BMPs of sediment transport for the years of 1986, 2000 and 2011 using SWAT. Moreover, this research tries to address the following specific objectives: to evaluate land use land cover change effects on stream flow of the watershed, to estimate and compare sediment yield of the watershed under different land use change, to characterize the watershed in terms of spatial variability of sediment, to assess the effects of developing best sediment management scenarios and To produce land cover map of Gilgel Abay watershed for each reference time.

Description of study area

Gilgel Abay watershed is situated in the north west part of Ethiopia between 10°56' to 11°51'N latitude and 36°44' to 37°23'E longitudes. The river originates from small spring located near Gish Abay town at an elevation of 2900m a.m.s.l and drains to the southern part of Lake Tana. The catchment area of Gilgel Abay River at the outlet to Lake Tana is around 4,021.8 km^2 and it is the largest tributary of Lake Tana basin which accounts around 30% of the total area of the basin. The elevation of Gilgel Abay catchment varies from 1787m to 3528m a.m.s.l. The major parts of the study area falls in Woina Dega climate however, small part of study area that is mainly at the South tips of the catchment falls in Dega Zone. The mean annual rainfall of the watershed is 1845mm. There is high diurnal change in temperature i.e. there is high variation between the daily maximum and minimum temperature [4]. The major soils types in this watershed are Haplic Luvisols and Haplic Alisols having coverage of 48.61% and 18.93 respectively.

Methods

Physically based SWAT model was used for assessing the impacts of land use cover change on stream flow and sediment yield of the watershed. For the satellite image classification ERDAS Imagine 2014 were used. Three different land use change and three best sediment management scenarios applied and evaluated based on each of the evaluation criteria. The performance of the model was checked through sensitivity analysis, calibration and validation by using Nash Sutcliff coefficient, NSE and coefficient of determination, R^2 evaluation criteria's.

The flow collected from gauging sites were summed up and transformed to the outlet to Lake Tana using catchment area ratio since the catchments have similar characteristics. Since the number of sediment data collected were too small; discharge versus sediment transport relationship rating curve were developed and the amount of sediment used for calibration at outlet to lake Tana were estimated. The SWAT weather generator parameters were estimated using pcpSTAT and Dewpoint 02. The consistency and homogeneity of hydro-meteorological data checked using double mass curve and Rainbow respectively.

Sensitivity analysis of SWAT simulation using 27 years recorded river flow and sediment was also done for identifying the most sensitive parameters. Calibration of flow and sediment simulations performed using the identified sensitive parameters for the periods 1995 – 2002 since the flow has no missing values during the record period. After a while, validation was done for the periods 2004 – 2007. The model performance was evaluated using Nash Sutcliff efficiency (NSE) and coefficient of determination (R^2).

Table 1 data types and sources

Type of Data	Description of Data	Data Source
Land use	30m resolution	USGS Glovis for 1986, 2000 & 2011
DEM	30 resolution	MoWIE
River flow	Upper Gilgel Abay, Koga and Kilti	MoWIE
Sediment	Upper Gilgel Abay, Koga and Kilti	MoWIE
Climate (RF, Temp, Hum, SR, Sunshine, Wind)	Bahir Dar, Adet, Dangila, Injibara, Wetet Abay	National Metrology Agency
Soil	FAO classified	MoWIE
GCP'S	Sample control points for different land uses	Field survey of the watershed

Results and Discussions

Land Use Land Cover Change Analysis

Based on recent studies; the map showing only five (cultivated, water, grassland, shrub land and forest) classes of land use cover were created for the years 1986, 2000 and 2011. Afterwards, spatial analysis of land cover performed to describe the overall land use/cover patterns throughout the watershed.

The accuracy assessment performed by using land use maps, 150 ground truth points and Google Earth. User's and producer's accuracy were greater than 85%, as well the overall accuracy of 92% for 2011 land use classification, which indicates the land sat and the methodologies used were so accurate. The Kappa coefficient were also, K= 0.9, which indicated the classification is almost perfect since it is greater than 0.8.

The cultivated land cover shows a dramatic increase during the first period (1986 – 2000) with +24.12% than the second period (2000 – 2011) with +9.67%, on the other hand shrub lands, water and forest showed a significant decrease in the first period. On the contrary grasslands showed a higher decrease during the second period (-14.39%) than the first period (-10.01%). These reveals that the changes in one land use cover resulted in a change in on the other land cover types.

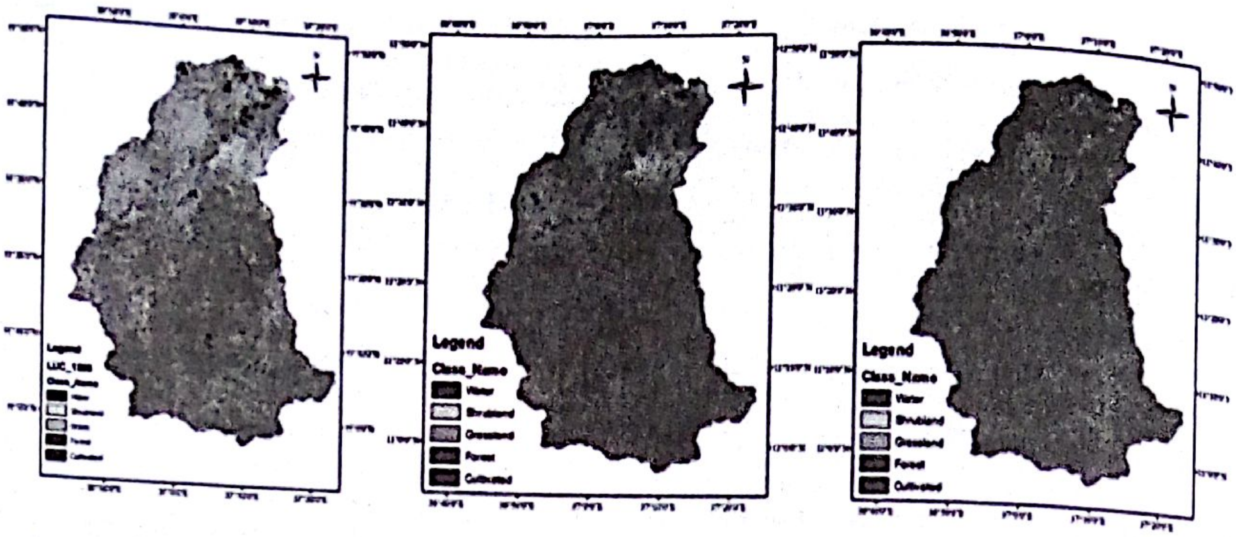


Figure 2 Land use land cover map of year 1986, 2000 and 2011

Table 2 Summary of land use cover change percentage of Gilgel Abay Watershed

Land cover classes	Years			Land use change detection		
	1986	2000	2011	1986-2000	2000-2011	1986-2011
Cultivated	33.69	57.76	67.48	+24.12	+9.67	+33.79
Water	5.61	4.08	5.06	-1.53	-0.98	-0.55
Grassland	36.17	26.16	11.72	-10.01	-14.39	-24.45
Forest	4.09	2.27	2.69	-1.79	+0.39	-1.4
Shrub Land	20.45	9.73	13.04	-10.72	+3.31	-7.41

Stream flow modeling

Sensitivity analysis of simulated stream flow for the watershed was performed using the daily observed flow for identifying the most sensitive parameter. 26 flow parameters were checked for sensitivity and seven sensitive parameters were identified. Calibration was done for sensitive flow parameters of SWAT with observed average monthly stream flow data. Manual and Sequential Uncertainty Fitting program (SUFI) flow calibration was performed for the simulated results based on the sensitive parameters.

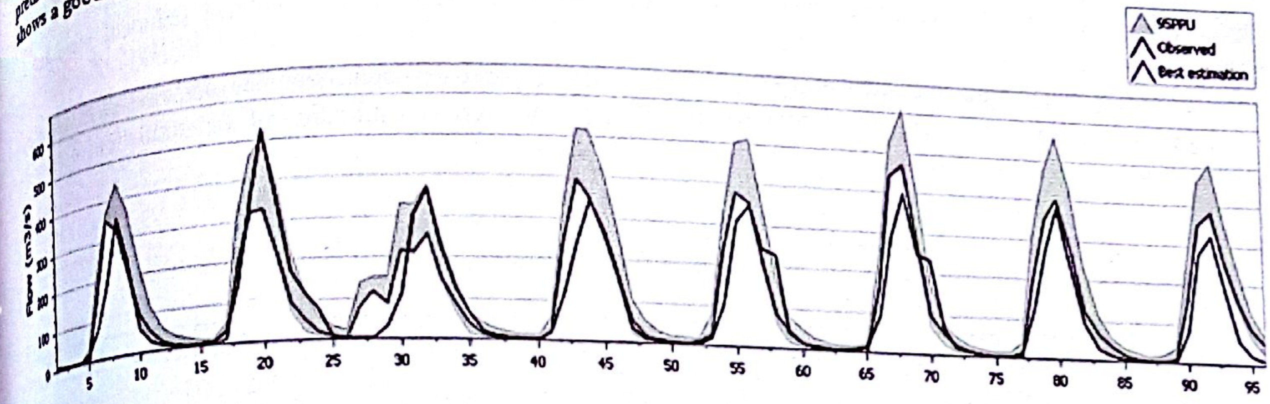
Table 3 Sensitive stream flow parameters

No.	Parameter name	Parameter value range	Default value	Calibrated value	Sensitivity	Significance
1	GWQMN	0 – 5000	0	4500	1	Very high
2	CH_K2	0 – 150	0	135	2	Very high
3	CN2	±25%		6.92	3	Very high
4	Canmx	0 – 10	0	7	4	High
5	GW_REVAP	0.02 – 0.2	0.02	0.086	5	High
6	ALPHA_BF	0 – 1	0.048	0.23	6	High
7	SOL_AWC	0 – 1	0.11	0.43	7	High

Table 4 Summary of calibrated and validated performance criteria's

Performance criteria	Calibration			Validation		
	1986	2000	2011	1986	2000	2011
NSE	0.85	0.78	0.80	0.79	0.82	0.77
R^2	0.89	0.90	0.88	0.88	0.93	0.90
RSR	0.04	0.05	0.05	0.07	0.06	0.07

The values of NSE and R^2 (Table 4) for the calibration and validation periods were greater than 0.77, which is good predictor of the model (i.e. it shows a good correlation and agreement with the observed mean). The RSR also shows a good estimation since the values are less than 0.07.



The calibrated and validated stream flow results showed a good agreement to the observed data (Figure 4). Therefore, these results of estimated stream flows indicate that SWAT model is good predictor of stream flow of Gilgel Abay watershed.

Evaluation of stream flow due to land use land cover change

Table 5 Mean annual stream flow results for the calibration and validation period

Years	1986	2000	2011	Change detection		
	Simulated	Simulated	Simulated	1986 -2000	2000-2011	1986-2011
Calibration	133.26	150.47	141.80	17.21	-8.67	8.54
Validation	134.68	137.72	140.55	3.04	2.83	5.87

The stream flow results for different years compared based on the validated values (Table 5). Stream flows has showed a higher increase in the first period (3.04m^3/s) than the second period (2.83m^3/s). In general, stream flows has increased throughout the study period for over 25 years period with a magnitude of 5.87m^3/s. These tremendous changes of stream flow were due to the land cover changes of the watershed (an increase of cultivated land trough study period).

Surface runoff results (Table 6) signify an increase by 33.62mm and 51.69mm for the first and second periods respectively, due to an increase of cultivated land. Surface runoff was increased with increased agricultural land because the potential for loss by runoff is increased from soil that is bare or partially bare during the cropping cycle. On the other hand, ground water flow decreased by 34.6m^3/s for the whole study periods (1986 – 2011), exemplified with an increase of cultivated land which leads a decrease of infiltration, as a result decreased lateral and ground water flow. Hence, this reveals that the ground water flow has showed an inverse relation with cultivated area of the watershed. The water yield (Table 6) of Gilgel Abay watershed has reflected a significant increase during the second period (2000 – 2011) with a magnitude increase by +61.73 mm. Moreover water yield has increased by 49.7mm from 1986 – 2011 due to most of the land uses were changed to cultivation.

Table 6 Annual hydrology of Gilgel Abay watershed

Year	Surf Q (mm)	Lat Q (mm)	GW Q (mm)	Water Yield (mm)	ET (mm)	PET (mm)	Sediment Yield (t/ha)
1986	274.6	263.24	996.03	1531.71	238.7	381.2	12.03
2000	312.22	257.69	952.46	1519.68	251.1	385.3	25.75
2011	363.91	258.84	961.43	1581.41	255.5	388.8	29.89

Sequentially base flow separation was done, to determine the portion of stream flow hydrograph that occurs from base flow and direct runoff or overland flow. The base flows of Gilgel Abay were evaluated on monthly basis. From the total stream flow around 69% were direct runoff and 31% were base flow. The base flow index is also 0.306.

Sediment yield modeling

Sensitivity analysis of simulated sediment yield for the watershed performed using the monthly-observed sediment yield for identifying the most sensitive parameter and for further calibration of the simulation of sediment yield.

Table 7 Sensitive sediment flow parameters

No.	Parameter name	Parameter value range	Default value	Calibrated value	Sensitivity	Significance
1	Spcon	0.0001 – 0.01	0.0001	0.0001	1	High
2	Ch_cov	0 – 1	0	0.8	2	High
3	USLE_P	0 – 1	1	0.1	3	High

During sensitivity, analysis of sediment, seven sediment parameters checked for sensitivity and sensitive parameters identified. From those parameters the first three (Spcon, Ch_cov and USLE_P) were highly sensitive and given to high priority for calibration. The simulation of sediment yield by the model with default parameter values has reflected relatively weak agreement with the observed sediment flow hydrograph. Hence, calibration had done for sensitive sediment parameters of SWAT with observed monthly sediment flow data.

Table 8 Performance evaluation of calibrated and validated sediment yield

Performance	Calibration			Validation		
criteria	1986	2000	2011	1986	2000	2011
NSE	0.86	0.83	0.79	0.83	0.85	0.75
R^2	0. 90	0.91	0.90	0.91	0.92	0.87
RSR	0.04	0.04	0.05	0.06	0.06	0.07

The calibrated and validated performance evaluation criteria's values for the three land use changes (Table 8) were good. As NSE, values are in between, 0.76 and 0.86 that shows the model-simulated values shows very good agreement with the observed sediment load, in addition the R^2 value was greater than 0.8 which indicates the simulated sediment yield best correlated with the measured sediment yield of Gilgel Abay watershed.

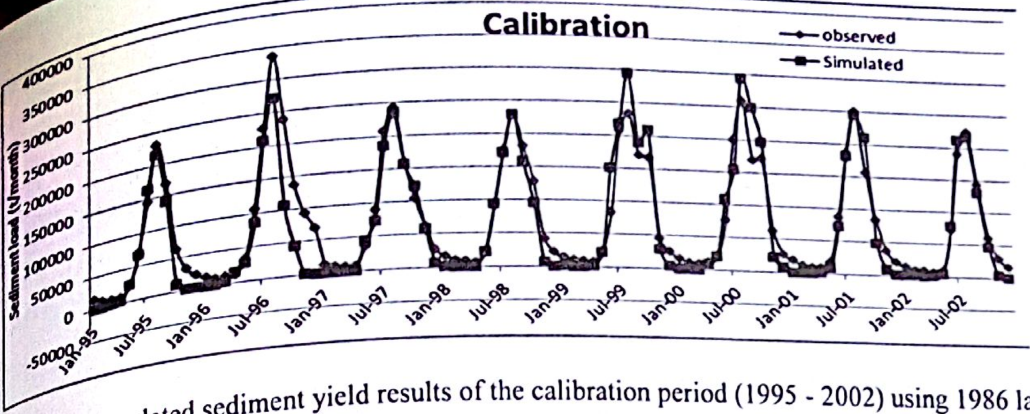


Figure 5 comparison of measured vs. simulated sediment yield results of the calibration period (1995 - 2002) using 1986 land use

Evaluation of sediment yield due to land use land cover change

Table 9 Calibrated and validated sediment yield (t/km²/year) results of Gilgel Abay watershed

Years	1986 Simulated	2000 Simulated	2011 Simulated	Sediment Change Detection 1986-2000	2000-2011	1986-2011
Calibration	207.49	242.15	245.07	34.66	2.92	37.58
Validation	168.41	208.42	231.19	40.01	22.77	62.78

For over twenty-five years period (1986 – 2011) there was an increase of agricultural area by 33.79% causing an increase of sediment yield by 62.78t/km². These indicated that land use change has a significant effect on sediment yield of Gilgel Abay watershed. This was due to cultivation caused loosening of soil layer sequentially resulting movement of a soil layer easily through water especially during peak flow periods, since sediment transport has a direct relationship with the river discharge. In general, the change in cultivated land has showed a direct relationship with sediment yield; while grassland and shrub land showed an inverse relation in Gilgel Abay watershed.

Spatial variability of sediment yield from Gilgel Abay watershed identified from the validated sediment outputs for each of the sub-basins. The average annual sediment yield out of reaches; during the time step in metric tons for each sub-basin were used to generate the sediment source map. The soil erosion or sedimentation levels in the basin were classified as low (0 – 20 t/ha/yr), moderate (20 – 50t/ha/yr), high (50 – 150t/ha/yr) and very high (>150t/ha/yr).

According to the sediment results; of the sub-basins in Gilgel Abay watershed (figure 11), sub-basins 30 and 31 were high, sub-basins 26, 29, 25 and 10 were moderate potential source area for sediment, and on the other hand sub-basin 23, 5, 3 and 1 were very low potential source area for sediment having less than 2.5t/ha/yr.

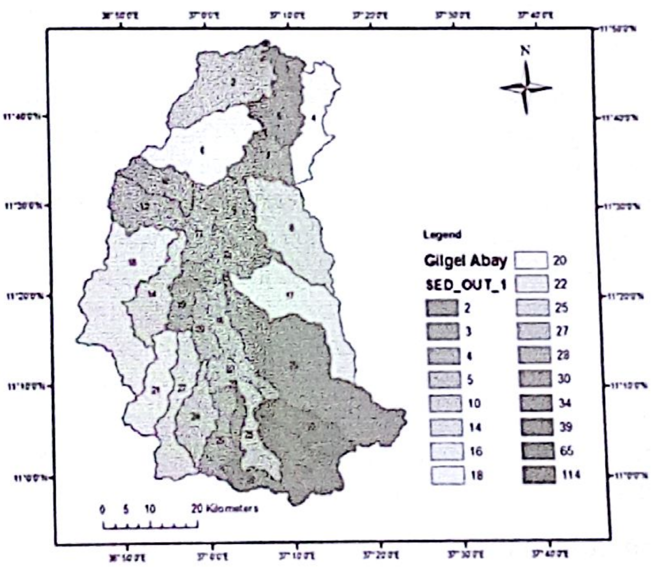


Figure 11Spatial distribution of sediment transported with water out of reach during time step (t/ha/yr) in Gilgel Abay watershed

The higher amounts of sediment temporal variability were occurred during June, July, August and September. This was due to high peak runoff was occurred during these months consequently results higher rate of soil erosion. On the other hand, very low rate of soil erosion (sediment movement) was occurred during dry seasons which had very small amount of flow.

Best Sediment management scenario development and analysis

According to spatial variability of sediment source and erosion level identified three different BMP scenarios were developed and compared according to their effectiveness of soil conservation or sediment reduction using SWAT model. In the Base case scenario (S0) the watershed existing conditions (2011 land use) were considered as a baseline for the other two scenarios' development and comparison. In scenario S1, filter strips placed on all agricultural HRUs, which are a combination of cultivated land, all soil types and slope classes. Stone bunds designed as scenario S2, by changing the parameter values of SLSUBBSN and USLE-P files on SWAT parameters database table. SLSUBBSN and USLE_P values modified on (.hru) and (.mgt) input tables respectively.

Table 10 Summary of Sediment management scenarios

Scenarios	Description	SWAT parameter used: Parameter name (input file)		Calibration value	Modified value	Performance of Validation R^2	NSE	Sediment yield ($t/km^2/yr$)	% reduction
S0	Base case					0.87	0.75	231.19	
S1	Filter strip	FILTERW		0m	1m	0.88	0.80	174.02	24.73
S2	Stone bund	SLSUBBSN	0-30%	60 & 24m	10m				
			>30%	9.14m	9m	0.88	0.80	181.82	21.36
		USLE_P		0.15	0.1				
S3	Reforestation	5% of Cultivated, grass land and shrub land				0.88	0.78	147.55	36.18

In Scenario S3, reforestation of 5% of cultivated, grassland and shrub lands from the recent (2011) land use cover considered and the amount of sediment reduction throughout the watershed estimated and compared with the other above two scenarios.

The sediment reductions ranged from 21% – 36% for the different management scenarios formulated during this study. Reforestation was the best effective method of sediment reduction in Gilgel Abay watershed. Those BMPs also have its own role on reduction of sedimentation of the proposed Gilgel Abay and Koga functional reservoir. As a result the sustainability of those two reservoirs will be increased. Hence the implementation and encouragement of those BMPs is very crucial for Gilgel Abay watershed development programs. Sedimentation of proposed Gilgel Abay reservoir will also decreased by 40% with implementing S3 (reforestation) scenario.

Conclusions

Gilgel Abay watershed has experienced a significant change in land use/cover over the past 25 years. Deforestation and increase of agricultural lands exhibited by rapid increase of human population, which changes the whole Gilgel Abay watershed in general, and some sub-watersheds in particular. Grasslands and shrub lands significantly changed to cultivated lands showing an identical trend for the two consecutive periods.

The changes in land use has resulted changes in stream flow, in which the expansion of agriculture results an increase of surface runoff, on the other hand, lateral and ground water flow decreases with an expansion of agriculture. The significant changes of stream were occurred in wet periods than dry periods. The water yield was also increased with an increase of cultivated land.

Sediment yield was dependent of land use/cover changes; hence, in Gilgel Abay watershed that has showed a significant land use/cover change implied a change to the amount of sediment yield flows out of the watershed. As a result, the sediment yield increased from year to year during the 25 years period due to a conversion of shrub lands and grasslands to cultivation. Over 25 years period (1986 – 2011) an increase of cultivated land by 33.79% resulted in an increase of sediment yield by 62.78t/km^2. Generally, sediment yield has showed a direct relationship with cultivated land as a result the sediment increased from year to year.

Sub watersheds 29, 30 and 31 were identified as more potential sediment source areas (highly erodible). Those sub watersheds indicated that, it requires attention for best management practices in the watershed. Reforestation was an effective means of watershed management in terms of sediment reduction. Moreover, filter strips showed 24.73%, reforestation 36.18% and stone bunds 21.36% sediment yield reduction.

References

Hari Krishna B*, R. Sai kumar, O. Sampath and T. Nagendher. (2014). A Review- Impact of land use land cover change and best management practices in a watershed by using swat model. *International Journal of Pure & Applied Bioscience.*

CSA. (2008). Summary and statistical report of the 2007 population and Housing census: population size by age and sex. Addis Ababa: Federal Democratic Republic of Ethiopia Population Census Commission.

SMEC. (2007). Hydrological Study of Tana Beles Sub-Basins, part I. Sub-Basins Ground water investigation report. SMEC International Pvt Ltd.

Rientjes, T. H. M.,0 Haile, A. T., Kebede E., Mannaerts, C. M. M., Habib E. and Steenhuis, T. S., (2011). Changes in land cover, rainfall and stream flow in Upper Gilgel Abbay catchment, Blue Nile basin, Ethiopia. Hydrol. Earth Syst. Sci., 15, 1979–1989, 2011. www.hydrol-earth-syst-sci.net/15/1979/2011/ doi:10.5194/hess-15-1979-2011

Green, W.H. and Ampt G.A., (1911). Studies on soil physics, 1. The flow of air and water through soils. Journal of Agricultural Sciences , 4: 11-24.

ASSESSMENT OF WATER QUALITY INDICATORS OF LAKE TANA, ETHIOPIA, USING REMOTE SENSING

Teshale T. Danbara[1], M. S. Salama[2], T.H.M. Rientjes[2], Essayas K. Ayana[1,3]

[1]*Bahir Dar University, Bahir Dar Institute of Technology, Faculty of Civil and Water Resources Engineering, Ethiopia*

[2]*Department of Water Resources, ITC, University of Twente, The Netherlands*

[3]*Columbia University in the City of New York*

(Corresponding author: Teshale Tadesse Danbara, E-mail: teshale2000@gmail.com, Tel: +251911065425, P.O. box: 26, Lecturer in Bahir Dar University, Bahir Dar Institute of Technology, Faculty of Civil and Water Resources Engineering)

ABSTRACT

Intensive sampling of water quality variables on many locations is prohibitively expensive. Techniques using remotely sensed images have become increasingly effective in estimating the most common water quality variables in the Lakes. The purpose of this study is to derive the water quality indicators of the Lake Tana from the recently launched Landsat-8 satellite images using in-situ measurement and hydro-optical inversion model. Radiometric measurements were carried out in September 2013 which is at the end of rainy season and the water quality variables were measured in September 2013 and in April, May and June 2015. The Hydrosat inversion model is selected for this study and modified to retrieve the water quality indicators of Lake Tana from Landsat-8 satellite images. Also an atmospheric correction scheme for Landsat-8 has been developed. Results of this study on applicability of Landsat-8 for retrieval of water quality indicators are promising. The field data has been used to calibrate and to validate the derived inherent optical properties (IOPs) using calibration and validation of geophysical observation model (GeoCalVal). The specific inherent optical property (SIOP) of suspended particulate matter (SPM) of Lake Tana has been estimated. The derived backscattering coefficient of suspended particulate matter (SPM) and the absorption coefficient of detritus and gelbstoff with the measured concentration of SPM have shown linear relationships with R-squared value of greater 0.7. From this study it has been able to investigate the time-space distribution of the water quality indicators of Lake Tana for four seasons. The study has shown that the most dominant water quality variable which predominantly affects the IOPs of Lake Tana is SPM.

Key Words: Lake Tana, Landsat 8, Water quality indicators, Hydro-optics, Remote sensing

Introduction

The sustainable management of fresh inland water systems requires the regular monitoring and assessments of its water quality. However, the conventional water quality measurement techniques are limited in their spatial and temporal coverage, expensive and time consuming. Measuring the water quality of inland lakes requires systematic advanced instrumentation. Using remote sensing based water quality data in conjunction with accurately measured field water quality data give reasonable and accurate optically significant constituents of water (Dekker et al., 2001; Salama et al., 2009). To determine the existing status of water quality and to avoid the future water catastrophe, assessing and monitoring water quality using remote sensing in conjunction with in-situ measurement plays a significant role (Salama et al., 2009).

Remotely sensed data provide synoptic information of water quality at high temporal frequency (Salama et al., 2009). A derivation of inherent optical properties (IOPs) from remote sensing reflectance is commonly based on modelling (Gordon et al., 1988b), which aim to describe the relationship between remote sensing reflectance and the inherent optical properties (IOPs). IOPs of natural waters including absorption coefficient from water molecules, phytoplankton pigments, detritus and dissolved organic matter and backscattering coefficient from water molecules and suspended particulate matters are the most significant parameters governing the light propagation within the water column (Li et al., 2013; Maritorena et al., 2002; Salama et al., 2009). Morel and Prieur (1977) showed that the water leaving reflectance is directly proportional to the backscattering coefficient and inversely proportional to the absorption coefficient.

Besides the remote sensing water quality data, field measurement is necessary to validate the adapted hydro-optical model. The field data is useful to assess the acceptable accuracy of the derived IOPs from hydro-optical inversion model. In this study, the relationship between the derived IOPs and measured concentration was evaluated using calibration and validation of geophysical observation model (Salama et al., 2012a). In-situ measurements are carried out in selected areas of Lake Tana. For each in-situ sample, downwelling irradiance and upwelling radiance, concentration of suspended sediment, colored dissolved organic matter (CDOM), turbidity, secchi depth and chlorophyll-a absorption were measured.

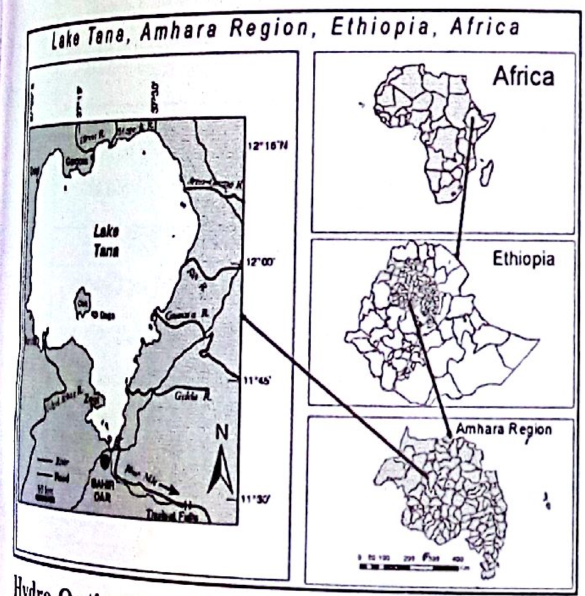
In this study the water quality indicators for data scarce Lake Tana region were derived from Landsat-8 images using in-situ measurement and Hydro-optical inversion model (Hydrosat) of Salama et al. (2012b). The model has been modified to derive water quality indicators from the Landsat-8 images and the atmospheric correction scheme for Landsat-8 satellite images has been developed.

Material and Methods

Study Area

Lake Tana is located at the northwest highlands' of Ethiopia at 12°0' N and 37°15' E. It is a shallow Lake with a mean depth of 9m and maximum depth of 15m (Kaba Ayana, 2007). The Lake covers the drainage area of 15096km^2 (Setegn et al., 2011) with its surface area between 3000 to 3600km^2.

Figure 1 Study Area, Lake Tana, Ethiopia



Hydro-Optical model to Estimate the IOPs

The hydro-optical model (Hydrosat) developed by Salama et al. (2012b) has been used in this study. The Hydrosat is a region and time independent remote sensing model that derives all possible water quality variables from Landsat images and does not require tuning with field measurements.

Atmospheric Correction

At the top of atmosphere the total reflectance is the result of several components (Gordon, 1997).

Where ($\rho_{t(\lambda)}$) is the total reflectance received by the sensor, $T_{g(\lambda)}$ is the gaseous transmittance, $T_{v(\lambda)}$ is the viewing diffuse transmittance, $\rho_{a(\lambda)}$ is aerosol scattering, $\rho_{r(\lambda)}$ is air molecules scattering, $\rho_{sfc(\lambda)}$ is the surface specular reflectance and $\rho_{w(\lambda)}$ is the water leaving reflectance. Top of atmospheric reflectance is obtained from Landsat-8 images. Air molecules scattering is computed from Gordon et al. (1988a) approach. The surface specular reflectance was neglected since only about 2% will be reflected (Preisendorfer, 1976). Gaseous transmittance can be calculated from Goody (1964) and Malkmus (1967).

$$\rho_{t(\lambda)} = T_{g(\lambda)}(\rho_{a(\lambda)} + \rho_{r(\lambda)} + T_{v(\lambda)}\rho_{sfc(\lambda)} + T_{v(\lambda)}\rho_{w(\lambda)})$$

The diffuse transmittance was approximated by using the model of Wang (1999). The water leaving reflectance ($\rho_{w(\lambda)}$) is resulting from the interaction between the light and the water quality constituents in the water column. The water leaving reflectance was derived by following the method of Salama et al. (2004);Salama and Shen (2010), and Salama et al. (2012b) as;

$$T_{v(\lambda)}\rho_{w(\lambda)} = \left(\frac{\rho_{t(\lambda)}}{T_{g(\lambda)}} - (\rho_{r(\lambda)} + T_{v(\lambda)}\rho_{sfc(\lambda)})\right) - \rho_{a(\lambda)}$$

The aerosol reflectance can be estimated by taking the aerosol ratio between the short and the long wavelengths and its value can be computed from the correlation between the corrected reflectance of band s and l (Salama et al., 2012b) of Landsat-8 as;

$$\varepsilon_{(s,l)} = \frac{\rho_{a(s)}}{\rho_{a(l)}}$$

$$\varepsilon_{(s,l)} = \cot[0.5\tan^{-1}(\frac{c_{ll}}{c_{ss} - c_{sl}})]$$

Where s is the short wavelength (865nm); l is the long wavelength (1610nm); and C is the correlation between corrected reflectance of s and l bands of Landsat-8. The C value of s and l bands can be obtained from the statistics of the bands in ENVI + IDL. The aerosol ratio $\varepsilon_{(s,l)}$ can also be extrapolated to find $\varepsilon_{(i,l)}$ for any other wavelengths (i) (Salama & Shen, 2010) as;

$$\varepsilon_{(i,l)} = \varepsilon_{(s,l)}^{\delta i} \quad \text{for} \quad i < s < l \quad \text{where} \quad \delta_i = \frac{(l-i)}{(l-s)}$$

The water leaving reflectance for other bands of Landsat-8 was computed as;

$$\rho_{w(\lambda)} = \frac{\rho_{c(i)} - \rho_{a(l)} * \varepsilon_{(s,l)}^{\delta(i)}}{T_{v(i)}}$$

$$\rho_{c(\lambda)} = \frac{\rho_{t(\lambda)}}{T_{g(\lambda)}} - (\rho_{r(\lambda)} + T_{v(\lambda)}\rho_{sfc(\lambda)})$$

Where is the corrected reflectance (Salama & Shen, 2010)

The purpose of atmospheric correction is to retrieve the water leaving reflectance.

Deriving the water quality indicators

The IOPs were derived by inverting the semi-analytical model (Gordon et al., 1988b) and following the matrix inversion method of Hoge and Lyon (1996) and Wang et al. (2005). To determine the unknown values of the water quality indicators the entire equation presented in Table 1 is written in matrix form as;

$$\begin{bmatrix} a_{ph(0.44)} \\ a_{dg(0.44)} \\ b_{b,spm(0.4)} \end{bmatrix} \begin{bmatrix} S_f a_{pico(\lambda 1)} + (1-S_f) a_{micro(\lambda 1)} & \exp(-s(\lambda 1 - 0.44)) & (\frac{0.4}{\lambda 1})^Y * x_{(\lambda 1)} \\ S_f a_{pico(\lambda 2)} + (1-S_f) a_{micro(\lambda 2)} & \exp(-s(\lambda 2 - 0.44)) & (\frac{0.4}{\lambda 2})^Y * x_{(\lambda 2)} \\ S_f a_{pico(\lambda 3)} + (1-S_f) a_{micro(\lambda 3)} & \exp(-s(\lambda 3 - 0.44)) & (\frac{0.4}{\lambda 3})^Y * x_{(\lambda 3)} \end{bmatrix} = \begin{bmatrix} -(b_{bw(\lambda 1)} * x_{(\lambda 1)} + a_{w(\lambda 1)}) \\ -(b_{bw(\lambda 2)} * x_{(\lambda 2)} + a_{w(\lambda 2)}) \\ -(b_{bw(\lambda 3)} * x_{(\lambda 3)} + a_{w(\lambda 3)}) \end{bmatrix}$$

Table 1 Equations to derive the water quality indicators

Equations	References
$Rrs_{(\lambda)} = g_1(\frac{b_{b(\lambda)}}{a_{(\lambda)} + b_{b(\lambda)}}) + g_2(\frac{b_{b(\lambda)}}{a_{(\lambda)} + b_{b(\lambda)}})^2$; Rrs is remote sensing reflectance; g_1 and g_2 are equal 0.0949 and 0.0794. $b_{b(\lambda)}$ and $a_{(\lambda)}$ are bulk backscattering and absorption coefficients.	(Gordon et al., 1988b)
$u_{(\lambda)} = \frac{b_{b(\lambda)}}{a_{(\lambda)} + b_{b(\lambda)}}$ and $x_{(\lambda)} = 1 - \frac{1}{u_{(\lambda)}}$,	
$a_{(\lambda)} = a_{w(\lambda)} + a_{ph(\lambda)} + a_{dg(\lambda)}$ Bulk absorption coefficient ($a_{(\lambda)}$), subscripts w, ph, and dg are for water, phytoplankton and detritus and gelbstoff respectively.	(Pope & Fry, 1997), (Mobley, 2004) or (Smith & Baker, 1981)
$a_{ph(\lambda)} = a_{ph(0.44)}(s_f a_{pico(\lambda)} + (1-s_f) a_{micro(\lambda)})$ Absorption coefficient of phytoplankton (a_{ph}), a_{pico} and a_{micro} are provided in Ciotti et al. (2002), S_f is the size parameter between zero and one.	(Ciotti et al., 2002)
$a_{dg(\lambda)} = a_{dg(0.44)} \exp(-s(\lambda - 0.44))$ s is the spectral exponent ranging between 0.008 and 0.03	(Bricaud et al., 1981); (Wang et al., 2005), (Babin et al., 2003);
$b_{b(\lambda)} = b_{b,w(\lambda)} + b_{b,spm(\lambda)}$ The bulk backscattering coefficient the subscripts w and spm are for water and suspended particulate matter.	
$b_{b,spm(\lambda)} = b_{b,spm(0.4)}(\frac{0.4}{\lambda})^Y$ Where 0.4 is wavelength in µm, Y is spectral slope and it value in between 0 and 2.5	(Salama & Stein, 2009); (Wang et al., 2005)

Data Collection

Field Data Collection

The field measurements were carried out at the end of rainy season in September 2013 and in April, May and June of 2015. The sampling days were selected based on the satellites over pass. Landsat-8 passes over the lake every 16 days around 10A.M. Water samples were collected for total suspended matter (TSM), Turbidity and Chlorophyll-a analysis. The radiometric and CDOM measurements were performed using TriOS-RAMSES (Radiation Measurement Sensor with Enhanced Spectral Resolution) hyperspectral spectroradiometer.

Satellite Image collection

Landsat-8 is the recently launched satellite which consists of two sensors namely, Operational Land Imager (OLI, 9 spectral bands) and Thermal Infrared Sensor (TIRS, 2 spectral bands). The OLI cover the visible, near-Infrared (VNIR) and Short Wave IR (SWIR) portions of the electromagnetic spectrum. From OLI bands 8 bands are acquired at 30m spatial resolution and the panchromatic band is acquired at 15m spatial resolution. The TIRS collects in thermal infrared region with 100-meter spatial resolution. Existing cloud free images of path 170 and raw 052 were downloaded from GloVis (http://glovis.usgs.gov/) and were processed in ENVI + IDL.

Results and Discussion

Atmospheric correction

The Hydrosat atmospheric correction method was applied to the Landsat-8 image after implementing the first order haze correction. The first order haze correction has been done by removing the resulting reflectance of cirrus band from the top of atmosphere reflectance of each other bands. The atmospheric corrected and the in-situ reflectance are well fit in green, red, and NIR bands than deep blue and blue bands. Therefore, the Hydrosat atmospheric correction method corrected well the bands from green to NIR. The accuracy of Hydrosat atmospheric correction method was evaluated through the comparison between the derived atmospheric corrected water leaving reflectance from the image and the measured water leaving reflectance and the result is presented in Table 2.

Table 2 Relation between Atmospheric Corrected and In-situ Measured Reflectance

Bands L-8	Wavelength (nm)	No. Samples	slope	intercept	R^2	RMSE [ratio]
Band 1	443	9	0.171	0.108	0.81	0.075118
Band 2	482	9	0.173	0.1	0.84	0.05701
Band 3	566	9	0.114	0.131	0.79	0.018434
Band 4	655	9	0.107	0.145	0.83	0.016246
Band 5	865	9	0.228	0.028	0.82	0.005548

To correct for the atmosphere residual, the difference between the atmospheric corrected reflectance and the in-situ measured water leaving reflectance was computed and fitted. From the fit curve equation, the delta value (□) for each band has been computed. The obtained delta value of each band can be tuned into Hydrosat atmospheric correction method to obtain the atmospheric corrected reflectance for the entire Landsat 8 image. The delta (□) has been computed from;

$$\delta(\lambda) = \frac{\log\left[\frac{\left(\rho_{TOA(\lambda)} - \rho_{w_{field(\lambda)}} - 0.0011 * \lambda^{-4.94}\right)}{\rho_{a(l)}}\right]}{\log \varepsilon(s,l)}$$

Where $\rho_{TOA(\lambda)}$ is the top of atmosphere reflectance, $\rho_{W field(\lambda)}$ is water leaving reflectance measured in the field, $\rho_{l(\lambda)}$ is aerosol reflectance at the longer wavelength, $\varepsilon(s,l)$ is aerosol ratio. For the verification of Hydrosat atmospheric correction equation the new delta (□) value has been introduced. The verification has reduced the RMSE more in deep blue and blue region than the other regions. Therefore, the delta (□) can only be used for the blue to green region of the spectra.

Water Quality Indicators

After verification of the Hydrosat atmospheric correction method the IOPs have been derived from the entire image data. The IOPs of the constituents can be linearly related to their concentrations through the specific inherent optical properties (SIOPs). The specific inherent optical property (SIOP) of SPM was computed using GeoCalVal model (Salama et al., 2012a). Derived backscattering coefficient of SPM at 443nm and the measured SPM concentration data have been randomly divided into Calibration (Cal) and Validation (Val) data sets. The Cal data set was used to derive the specific inherent optical property of SPM at 443nm and the Val data set was used to check the validity of the model to derive IOPs. The mean R-squared, slope (SIOP), intercept and mean absolute error (MAE) computed from the model have been presented in Table 3.

Table 3 Calibration and Validation outputs

	R square (R^2)	Slope ($b_{b,spm}$*(443))	Intercept	Mean absolute Error (MAE)
$b_{b,spm}(443)$	0.72	0.0091 (m^2/g)	0.5766(m^{-1})	13.57 (g/m^3)

The concentrations of water constituents can be retrieved from the IOPs knowing the specific inherent optical properties of these constituents. The derived SPM concentration versus the measured concentration was correlated with R^2 value of greater than 0.7. Therefore, there is a linear relationship between derived and measured concentration of SPM.

For the spatiotemporal analysis four Landsat-8 images of the dry season, the peak rainy season, the end of rainy season and shortly after the end of rainy season have been selected and evaluated. The presence of suspended and dissolved matter in the waters increases both the scattering and absorption. Morel and Prieur (1977) studied that the increase in backscattering increases the water leaving reflectance more or less uniformly in every part of the spectrum. However, the increase in absorption decreases the water leaving reflectance. The backscattering is from the water molecule and suspended particulate matter, and the absorption is from the water molecule, detritus, gelbstoff and chlorophyll-a pigments. Furthermore, in the infrared region the water absorbs predominantly and the resulting scattering is due to the presence suspended particulate matter (Salama et al., 2009).

Figure 2 The absorption of detritus and gelbstoff at 443nm for the images of dry period, peak rainy season, end of rainy season, and shortly after the end of rainy season from left to right.

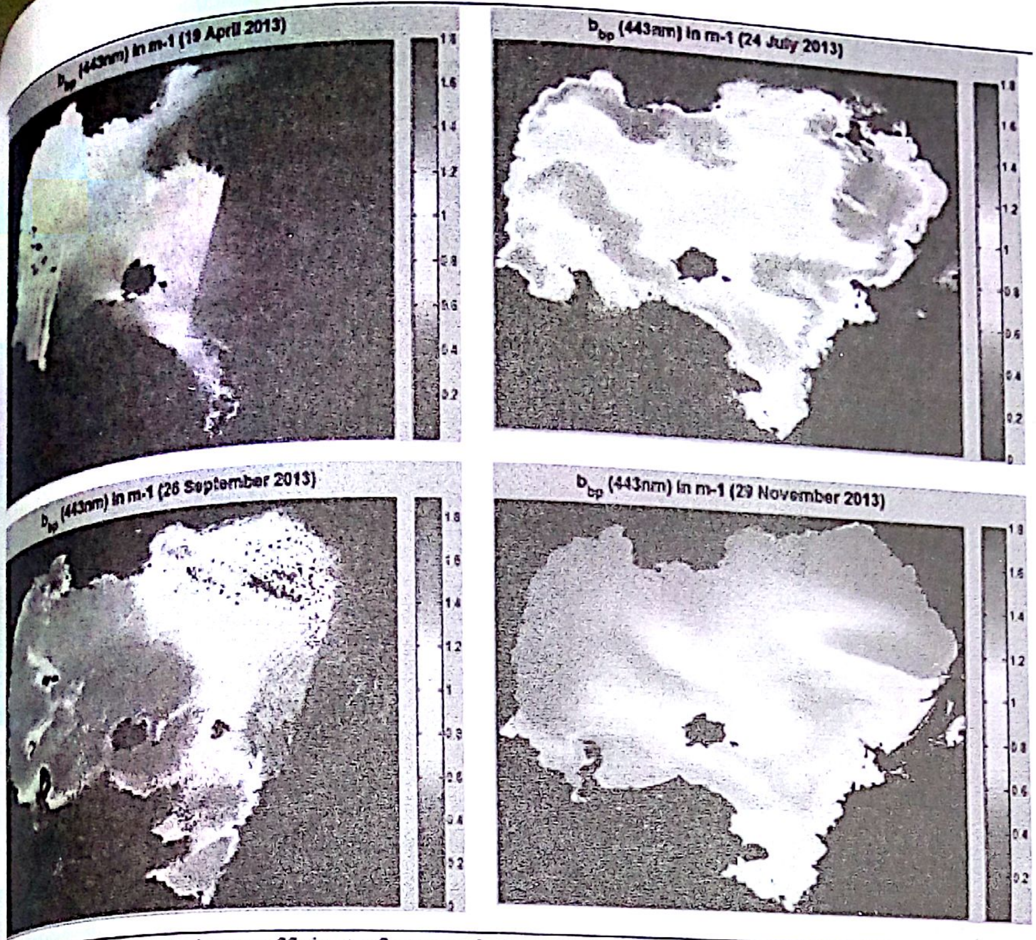


Figure 3 The backscattering coefficient of suspended particulate matter of Lake Tana for four different periods. Dry period, peak rainy season, end of rainy season and shortly after the end of rainy season from left to right.

Conclusion

The Hydrosat originally developed to derive the water quality variables from Landsat Enhanced Thematic Mapper-plus (Landsat-ETM) has been modified to retrieve the water quality indicators from Landsat-8. The original Hydrosat considered the reflectance from four bands of Landsat-ETM, three in visible and one in near infrared (Salama et al., 2012b). While in addition to shortwave infrared (band-6) and cirrus (band-9) of OLI bands, which have been used in atmospheric correction process, the modified Hydrosat considers five Landsat-8 OLI bands for the water quality retrieval, four in visible and one in NIR. Therefore Landsat-8 has been found reliable to derive the water quality indicators of the lakes and its spectral setup has improved the accuracy of IOPs retrieval. Newly added band-1 can be used to derive the water quality indicators and band-9 can be used for the first haze correction.

The derived IOPs (a_{gd}, and $b_{b\ spm}$) and measured SPM concentration showed a strong linear relationship with R^2 value of greater than 0.7. However during rainy season the relation between absorption of detritus and gelbstoff with measured CDOM concentration is weak; and the phytoplankton effect can be neglected. Therefore the most important optically significant constituent of the Lake Tana is SPM. The estimated specific backscattering coefficient (SIOP) of SPM ($b^*_{b,spm}$ (443)) of Lake Tana is $0.0091 m^2/g$. The estimated value of SIOP of SPM at 443nm has been considered as spatially constant and resulted in reliable retrieval of SPM with R^2 value greater than 0.7.

The time-space distribution of the water quality indicators of Lake Tana has been investigated for four seasons. The absorption of detritus and gelbstoff is high along the lake shore and the backscattering coefficient of SPM is low across the lake in dry season. In peak rainy season the IOPs are distributed within the same pattern across the lake and their higher values are observed along the lake shore and in the rivers outlet area. At the end of rainy season the absorption coefficient of detritus and gelbstoff is high across the lake and the backscattering coefficient of SPM is high in the west part of the lake. Furthermore, the IOPs are distributed across the lake with the higher value in the northern part shortly after the end of rainy season. The study has shown that the most dominant water quality variable which predominantly affects the IOPs of Lake Tana is SPM. The main source of SPM in Lake Tana is the sediment load from the tributaries and from the erosion of the agricultural land around the lake during rainy season.

References

Babin, M., Stramski, D., Ferrari, G. M., Claustre, H., Bricaud, A., Obolensky, G., & Hoepffner, N. (2003). Variations in the light absorption coefficients of phytoplankton, nonalgal particles, and dissolved organic matter in coastal waters around Europe. Journal of Geophysical Research: Oceans, 108(C7), 3211. doi: 10.1029/2001JC000882

Briucaud, A., Morel, A., & Prieur, L. (1981). Absorption by dissolved organic matter of the sea (yellow substance) in the UV and visible domains. Limnology and Oceanography, 26(1), 43-53. doi: 10.4319/lo.1981.26.1.0043

Ciotti, A. M., Lewis, M. R., & Cullen, J. J. (2002). Assessment of the relationships between dominant cell size in natural phytoplankton communities and the spectral shape of the absorption coefficient. Limnology and Oceanography, 47(2), 404-417.

Dekker, A. G., Vos, R. J., & Peters, S. W. M. (2001). Comparison of remote sensing data, model results and in situ data for total suspended matter (TSM) in the southern Frisian lakes. Science of The Total Environment, 268(1–3), 197-214. doi: http://dx.doi.org/10.1016/S0048-9697 (00)00679-3 Goody, R. (1964). Atmospheric radiation: Clarendon Press (Oxford).

Gordon, H. R. (1997). Atmospheric correction of ocean color imagery in the Earth Observing System era. Journal of Geophysical Research-Atmospheres, 102(D14), 17081-17106. doi: 10.1029/96jd02443

Gordon, H. R., Brown, J. W., & Evans, R. H. (1988a). Exact Rayleigh scattering calculations for use with the Nimbus-7 Coastal Zone Color Scanner. Appl. Opt., 27(5), 862-871. Gordon, H. R., Brown, O. B., Evans, R. H., Brown, J. W., Smith, R. C., Baker, K. S., & Clark, D. K. (1988b). A semianalytic radiance model of ocean color. Journal of Geophysical Research: Atmospheres, 93(D9), 10909-10924. doi: 10.1029/JD093iD09p10909

Hoge, F. E., & Lyon, P. E. (1996). Satellite retrieval of inherent optical properties by linear matrix inversion of oceanic radiance models: an analysis of model and radiance measurement errors. Journal of Geophysical Research, 101(C7), 16631-16616,16648.

Kaba Ayana, E. (2007). Validation of radar altimetry lake level data and it's application in water resource management. ITC, Enschede.

Li, L., Li, L., Song, K., Li, Y., Tedesco, L. P., Shi, K., & Li, Z. (2013). An inversion model for deriving inherent optical properties of inland waters: Establishment, validation and application. Remote Sensing of Environment, 135 (0), 150-166. doi: http://dx.doi.org/10.1016/j.rse.2013.03.031

Malkmus, W. (1967). Random Lorentz Band Model with Exponential-Tailed S-1 Line-Intensity Distribution Function. J. Opt. Soc. Am., 57(3), 323-329.

Maritorena, S., Siegel, D., & Peterson, A. (2002). Optimization of a semianalytical ocean color model for global-scale applications. Applied Optics, 41(15), 2705-2714.

Mobley, C. D. (2004). Light and water: Radiative transfer in natural waters (Vol. 592): Academic press San Diego. Morel, A., & Prieur, L. (1977). Analysis of variations in ocean color. Limnol. Oceanogr., 22(4), 709-722. Pope, R. M., & Fry, E. S. (1997). Absorption spectrum (380-700 nm) of pure water. II. Integrating cavity measurements. Appl. Opt., 36(33), 8710-8723. Preisendorfer, R. W. (1976). Hydrologic Optics: Introduction (Vol. 1): US Dept. of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Pacific Marine Environmental Laboratory.

Salama, M., Velde, R., Woerd, H., Kromkamp, J., Philippart, C., Joseph, A., O'Neill, P., Lang, R., Gish, T., & Werdell, P. (2012a). Technical Note:

Calibration and validation of geophysical observation models. Biogeosciences, 9(6), 2195-2201.

Salama, M. S., Dekker, A., Su, Z., Mannaerts, C. M., & Verhoef, W. (2009). Deriving inherent optical properties and associated inversion-uncertainties in the Dutch Lakes. Hydrology and Earth System Sciences, 13(7), 1113-1121.

Salama, M. S., Monbaliu, J., & Coppin, P. (2004). Atmospheric correction of advanced very high resolution radiometer imagery. International journal of remote sensing, 25(7-8), 1349-1355.

Salama, M. S., Radwan, M., & van der Velde, R. (2012b). A hydro-optical model for deriving water quality variables from satellite images (HydroSat): A case study of the Nile River demonstrating the future Sentinel-2 capabilities. Physics and Chemistry of the Earth, Parts A/B/C, 50–52 (0), 224-232. doi: http://dx.doi.org/10.1016/j.pce.2012.08.013

Salama, M. S., & Shen, F. (2010). Simultaneous atmospheric correction and quantification of suspended particulate matters from orbital and geostationary earth observation sensors. Estuarine, Coastal and Shelf Science, 86(3), 499-511. doi: http://dx.doi.org/10.1016/j.ecss.2009.10.001

Salama, M. S., & Stein, A. (2009). Error decomposition and estimation of inherent optical properties. Appl. Opt., 48(26), 4947-4962.

Dam Breach Modelling and Flood Inundation Mapping: A Case Study on Kesem Dam

Yared Michael Gebregziabher[1], Nigussie Teklie(Dr.-Ing.)[2] and Yohannis B. Tadesse (MSc)[3]

[1]Water Works Design and Supervision Enterprise (WWDSE), yaredmichael2@gmail.com Correspondence: Mobile: +251 -911 09 04 49, P.o.Box 18558, Addis Ababa, Ethiopia

[2]Water Works Design and Supervision Enterprise (WWDSE), nigussie.teklie@gmail.com

[3]Institute of River and Coastal Engineering, Hamburg University of Technology, Germany, yohanb2006@yahoo.com

Abstract

This paper presents dam breach analysis for Kesem Dam, dam constructed recently in Awash river basin on Kesem River found in central Ethiopia, and subsequent flood inundation mapping by applying well known dam breach analysis and flood routing methods.

The dam has been simulated for both overtopping and piping failure modes using the model BREACH. A probable maximum flood that may overtop the dam has been computed using Hershfield's technique and a value of 2,840m^3/s has been obtained. Overtopping failure would not be expected as the spillway could evacuate this flood safely. Piping failure mode was tested at different piping elevations, inflow scenarios and initial breach size. A combination of piping elevation of 888m a.m.s.l and initial breach size of 0.5m provokes dam to failure and gives the most catastrophic flood hydrograph with peak value of 92,000 m^3/s. The resulting peak outflow hydrograph was routed downstream with the 1D-flood routing model HEC-RAS and flood inundation mapping was produced with the models HEC-GeoRAS. The obtained inundation map shows that the factory site, Saburie town, different resettlement villages and the sugar cane irrigation farms are at risk of flooding in an event of dam break.

Introduction

General

Dams have been constructed throughout the world starting from the ancient times. Nevertheless, hundreds of dams have been reported to have failed and caused catastrophic damages on lives and properties of downstream areas. The major causes of dam failure are quality of construction, hydrodynamic movements in the reservoir, magnitude of inflow, performance of the dam and its appurtenance structures, among others. The common modes of failure are overtopping failure, piping failure, and sliding or foundation failure.

In Ethiopia construction of dams is increasing both in number and type, ranging from small micro earth dams to mega projects such as that of the Grand Ethiopian Renaissance Dam (GERD). Despite their purpose of retaining water in their reservoirs, dams have large risk when failed due to excessive inflow or seepage through the body. This demands the need for dam break pre-event analysis to predict the dam breach parameters, outflow magnitude and its downstream nature of propagation, so that preventive measures can be put in place to avert catastrophic damages. Pre-event dam failure analysis is not common practice in Ethiopia and this culture need to be changed. This paper presents dam break analysis for Kesem Dam. Kesem Dam is chosen for this analysis because some early indicators of dam failure such as seepage of water on downstream side of the abutment are seen after construction of the dam is completed.

The dam has been tested for a possible failure under different failure scenarios and modes using the dam break model BREACH. The output of BREACH model is a dam break outflow hydrograph. As a second step, the outflow hydrograph is routed downstream using the 1D flood routing model HEC-RAS to determine extent of downstream flood inundation.

Description of the Study Area and the Dam under Analysis

The Kesem Dam and Reservoir is located in Awash Fentale Wereda and Zone 3 of the Afar Regional State in the middle sub basin of Awash River basin, Figure 1. Kesem Dam is a rock fill embankment dam and is designed to accommodate a full PMF of 9,237m^3/s and the MFL level is 939.5m a.m.s.l. (WWDSE, 2005).

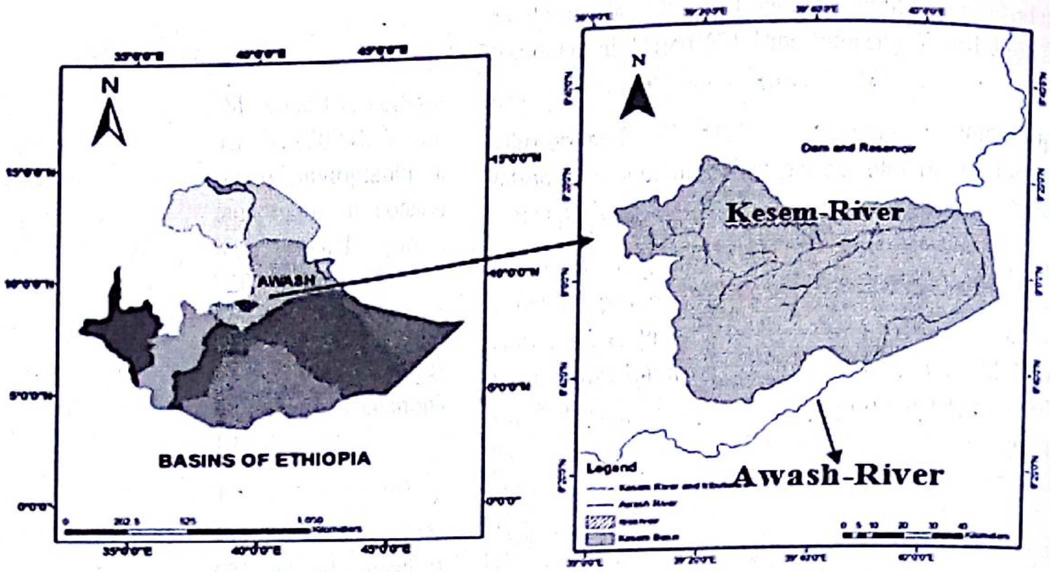


Figure 1: Location map of the study area

Methods

The models used in the whole course of study are: Digital Elevation Model (DEM) with 30mx30m resolution, ArcGis9.3, HEC-RAS. HEC-GeoRAS, BREACH model, among others.

Estimation of PMF

Initially primary and secondary data have been collected. Hydrology of the catchment is studied to determine the probable maximum flood (PMF) using Hershfield's statistical estimation method (WMO, 2009) and unit hydrograph concept and finally PMP of 2,840 m^3/s has been computed.

Breach Analysis

The model BREACH simulates both overtopping and piping mode of failures separately (Fread D. , 1991). The model can predict size, shape and time of breach formation. It is developed based on the principles of hydraulics, sediment transport, soil mechanics and it considers dam geometry, reservoir characteristics and dam material properties. When checked for overtopping failure using the model BREACH, the dam could safely evacuate the flood through spillway. For the case of piping failure, an elevation of 888m a.m.s.l gives the worst failure condition in terms of both breach size and outflow hydrograph. All results and discussions are given under section 3.

Flood Routing

The breach outflow discharge is routed through downstream channel and flood plain using the model HEC-RAS. The model applies Saint Venant's implicit finite difference solution for unsteady flow. The basic unsteady flow equations (Brunner, 2002) are:

Conservation of mass,

$$\frac{\partial A_T}{\partial t} + \frac{\partial Q}{\partial x} - ql = 0$$

Conservation of momentum,

$$\frac{\partial Q}{\partial t} + \frac{\partial QV}{\partial x} + gA\left(\frac{\partial z}{\partial x} + S_f\right) = 0$$

The geometry data required are initially extracted from DEM using HEC-GeoRAS at a pre-processing stage. Setting up all data such as boundary flow conditions, initial flow condition, and manning's roughness coefficient the flow is routed on HEC-RAS and results are exported back to HEC-GeoRAS to produce different maps like areal extent, depth and velocity maps.

To estimate the manning's roughness coefficient of river channel, the size and distribution of boulders and the type and density of trees within the channel examined during field visit and have been correlated with standard tables such as, Chow, 1988 and appropriate values have been estimated. For the upstream boundary condition the flow discharge through the dam breach is used. For the case of downstream boundary condition, normal depth of flow is adopted.

Results and Discussions

Determination of PMF flowing to the dam reservoir

By convoluting areal average rainfall computed by Thiessen's polygon technique up on the representative unit hydrograph of the catchment, a PMF with peak discharge of 2,840 m^3/s was computed. The total hydrograph is given on Figure 2 below.

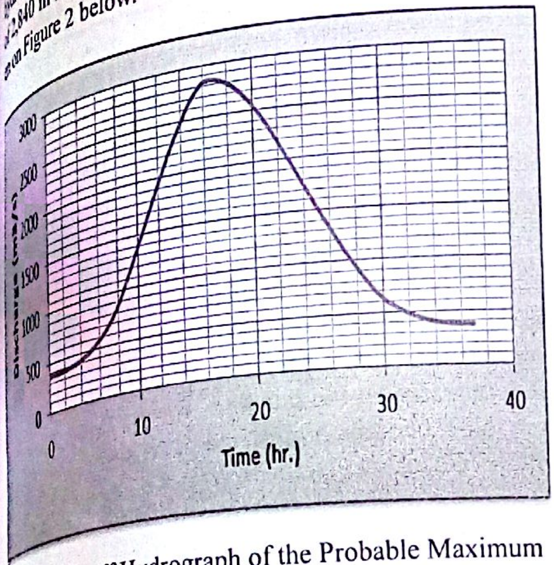


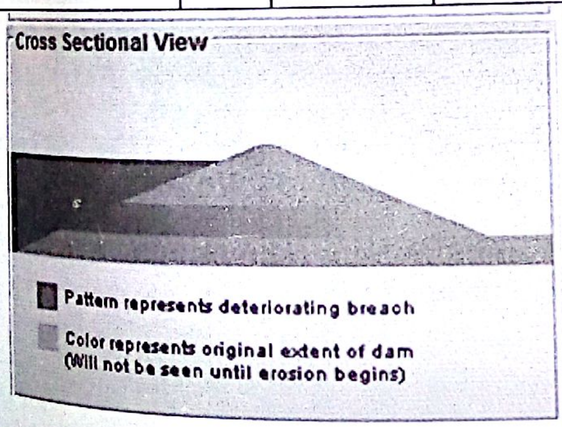
Figure 2: Runoff Hydrograph of the Probable Maximum Flood (PMF)

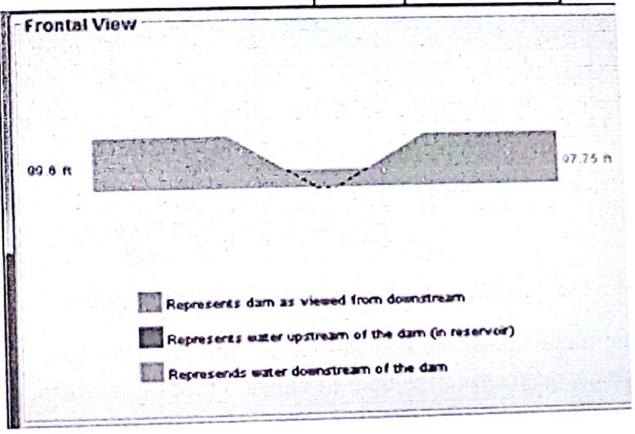
Breach Modelling

Both overtopping and piping failure modes were checked. The PMF could safely be evacuated through the spillway and no breaching was observed. Hence, the dam is safe against overtopping failure. The dam could potentially fail due to piping flow emerged at different elevations. After conducting sensitivity analysis, the dam fails giving the most catastrophic flood at piping elevation of 870m a.m.s.l. The reservoir water discharges out with in 5.34hrs. As shown on Figure 3, after 1hr. of seepage, piping flow is developed and further erosion continues and overburden material above the pipe collapses at 1.57hr. The following table gives a generalized output of the model. An outflow hydrograph with peak value of 92,000m^3/s is obtained, Figure 4

Table 1 Major Output of the Model

Description	Unit	Quantity	Description	Unit	Quantity
Top Width	m	275.17	Peak outflow	m^3/s	92,037.88
Bottom Width	m	27.23	Total failure time	hr.	6.09
Depth	m	85	Time to peak	hr.	2.41
Bottom Elevation	m	0.00	Final elevation of water surface	m	30.54
Side Slope	m/m	1.46			





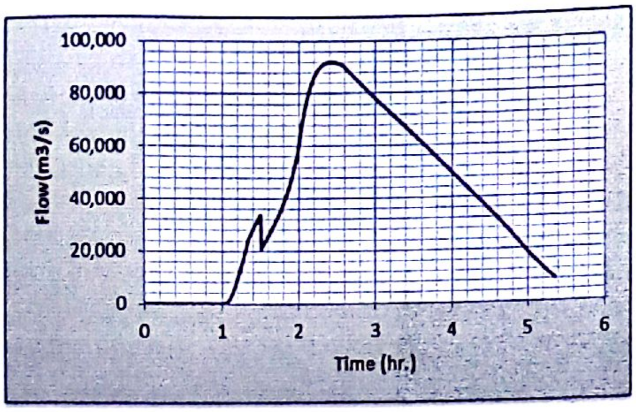


Figure 4 Total Outflow Hydrograph in m^3/s

Flood Routing and Mapping

The peak outflow through the breach is routed downstream and cross-sectional outputs showing the top water surface extent, its elevation and velocity distribution are obtained, Figure 5. The velocity reaches up to 17m/s along the river channel since it is a well formed route with lower value of manning's coefficient and at the adjacent sugar cane plantation which has n value of 0.04, it gradually decreases up to 3.0m/s. The velocity at any location is shown on figure 6.

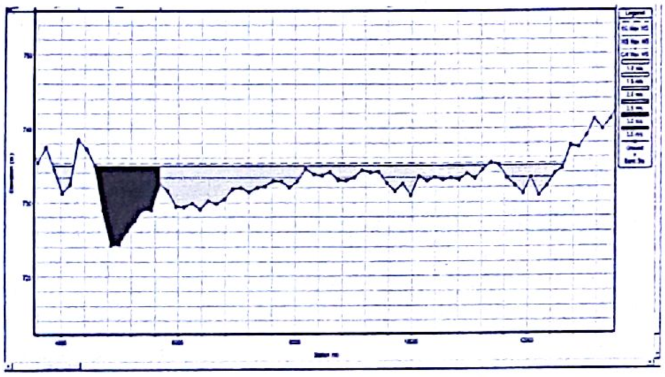


Figure 5 Cross-Sectional View of Model Output

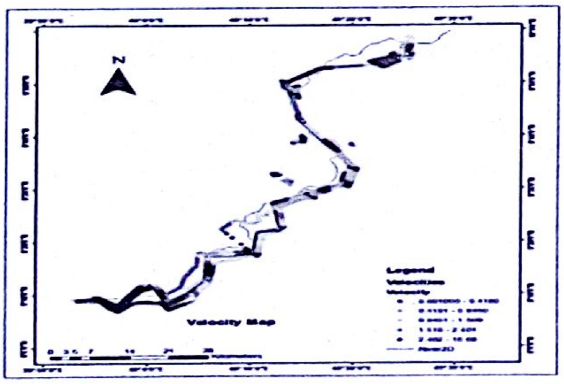
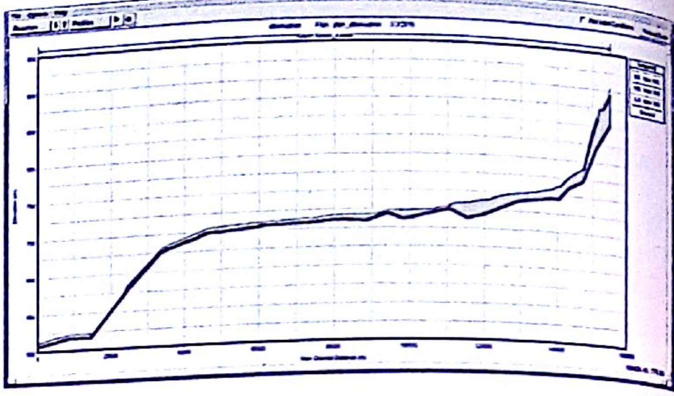


Figure 6 Velocity Map

Figure 7 General Profile View throughout the Reach



Water depth along the channel varies from 64m at immediate downstream of the dam to almost nil at downstream end of the study area, figure 7. This is because the cross-section at upstream end is narrow and deep whereas it goes wide and shallow towards downstream end. The velocity also decreases to a value less than 1m/s and it can be deduced that the flood impact and risk is minimum at downstream end. The maximum water surface area map given on figure 7 (A) indicates that all infrastructures on the right bank and the irrigation farms on left bank partly are inundated and the total area flooded during the maximum flood time is 316.31Km^2. The flood is

highly concentrated around the confluence of Kesem River with Awash River. This is because of the plain nature of the topography at the mouth of Kesem River. The flood then joins the river Awash and flows within the channel with overbank spills for a distance of around 40kms downstream until it attenuates.

Depth of flow at any location is given on figure 7 (B). The depth of flood in the factory compound for instance ranges from 0 to 20m. The downstream side of left irrigation area is flooded with a maximum depth of 12m whereas the right side farm and resettlement villages are inundated with average depth of 8m. The flood continues with average depth of 6m up to a distance of 30km downstream from the confluence point of the two rivers and it diminishes to almost negligible depth. highly concentrated around the confluence of Kesem River with Awash River. This is because of the plain nature of the topography at the mouth of Kesem River. The flood then joins the river Awash and flows within the channel with overbank spills for a distance of around 40kms downstream until it attenuates.

Depth of flow at any location is given on figure 7 (B). The depth of flood in the factory compound for instance ranges from 0 to 20m. The downstream side of left irrigation area is flooded with a maximum depth of 12m whereas the right side farm and resettlement villages are inundated with average depth of 8m. The flood continues with average depth of 6m up to a distance of 30km downstream from the confluence point of the two rivers and it diminishes to almost negligible depth.

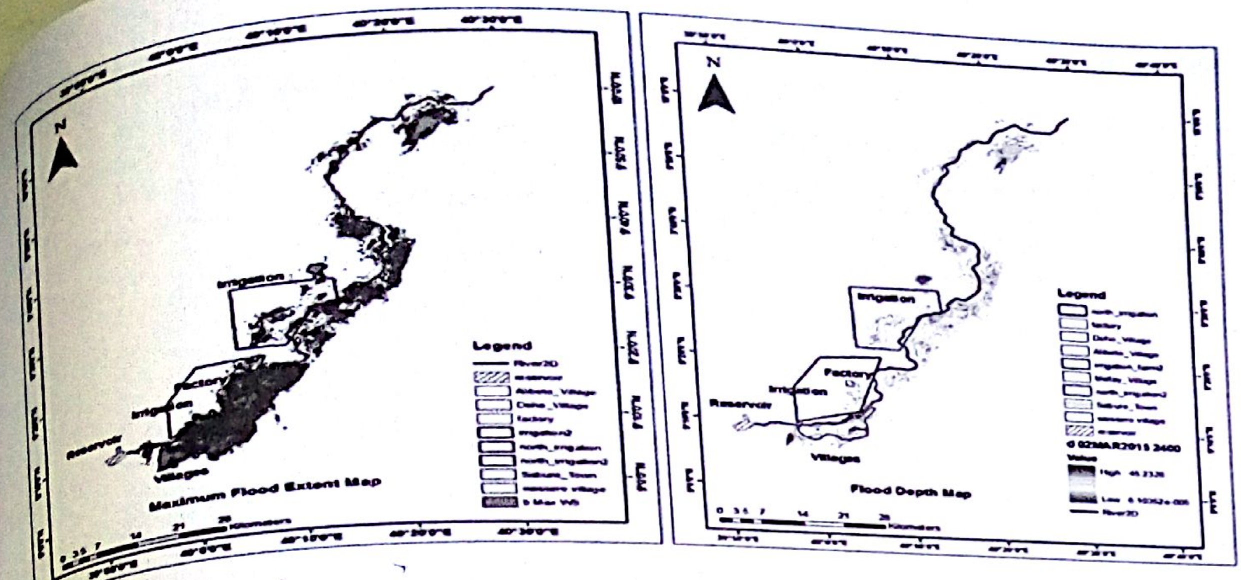


Figure 8 Maximum Flood Extent Map (A) and_Water Depth Map after 2hrs. (B)

The peak value of the hydrograph decreases downstream and the shape of hydrograph flatten, Figure 9. The flood peak value starts to attenuate at about 75kms from the dam site.

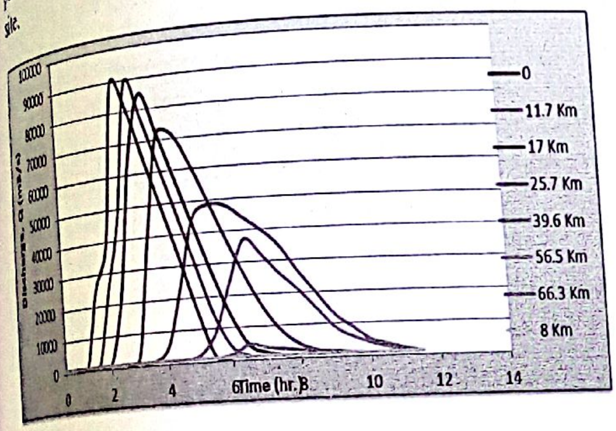


Figure 9: Flood hydrograph at different stations downstream of the dam

Conclusions and Recommendations

Conclusions

The dam is safe from breaching out due to overtopping failure mode.

The dam breaches due to piping mode of failure and a catastrophic flood with peak outflow of 92,000m^3/s passes through the breach for a piping elevation of 32m above river bed.

The breach outflow inundates an area of 316.31km^2. The depth of the flood ranges from 0 to 20m on the flood plains and goes up to 64m within the channel. The velocity ranges from 0 to 16.69m/s.

The right side irrigation farm at downstream of Saburie weir is totally inundated whereas the left side farms are partly flooded. All resettlement villages are drowned while some of part of Saburie town is submerged.

Recommendations

This research can be refined by using actual surveying data or high resolution DEM data.

The results of this study can be re-checked using different dam breach and flood models with higher accuracy and strong computational algorithms, such as 2D and 1D-2D hybrid models.

A safe way drain should be provided for the seepage on immediate downstream abutments

Flood damage analysis for the factory, villages, and irrigation farms should be done.

Safety of the dam should be monitored at different times and remedial actions have to be made on identified problems.

Flood protection dykes should be implemented to protect downstream infrastructures.

Emergency Action Plans (EAP) should be set in order to evacuate people potentially at risk.

Acknowledgments

My heartfelt gratitude goes to my advisor Dr.-Ing. Nigussie Teklie for his initial motivation, continuous follow-ups and helpful advices. I would also like to thank Mr. Yohannis Tadesse (PhD Student) who helped me in setting up my proposal clearly and developing the research from beginning to end.

Bibliography

Brunner, G. W. (2002). HEC-RAS, River Analysis System Hydraulic Reference Manual. Davis: US ARMY CORPS OF ENGINEERS.

Chow, V. T. (1988). OPEN-CHANNEL HYDRAULICS. Illinois: McGraw-Hill Book Company.

Fread, D. (1991). BREACH: An Erosion Model for Earthen Dam Failures. Silver Spring: Hydrology Laboratory, National Weather Service.

WMO, W. M. (2009). Manual on Estimation of Probable Maximum Precipitation. Geneva: World Meteorological Organization.

WWDSE. (2005). Final Dam Design Report. Addis Ababa: Water Works Design and Supervision Enterprise.

Determination of Supplementary Irrigation Requirement and Schedule for Sorghum in Kobo Girana Valley, North Eastern Amhara

[1,2]Zeleke Belay Admasu and [1,2] Solomon Wondatir

[1]Amhara Region Agricultural Research Institute, P.O.Box 527 Code 100 Bahir Dar, Ethiopia.

[2]Sirinka Agricultural Research Center, P.O.Box 74, Weldiya Ethiopia

Corresponding Author E-mail: zelebelay70@yahoo.com

Abstract

Supplemental irrigation is the application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth to increase and stabilize yields. The experiment was carried out over two cropping seasons (2011 to 2012) at Kobo adaptive irrigation research center, in North Eastern Amhara. Mean annual rainfall in the area is 630 mm, with considerable year-to-year variation and an average effective rain fall of 232.4mm in the growing season. The soil type silt loam with average filed capacity and permanent wilting point of 17.57% and 12.3% on volume basis accordingly with PH value of 7.8. Seven treatments were tested with RCBD experimental design with three replication. Statistical analysis was applied using SAS soft ware to test the effects of treatments on grain yield, head weight, water productivity. The experimental analysis indicated that there was a significant difference in head weight, grain yield and water productivity. As observed in the experimental years the grain yield widely ranges from 5.397 ton/ha to 1.53 ton/ha. Supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application gave the highest stalk biomass of 11 ton/ha and grain yield 5.397 ton/ha and it had a maximum yield advantage 2.874 ton/ha compared with the controlled system in 2011 cropping season. In the second year supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application with a seasonal water amount of 330.6mm had a yield advantage of 1.607ton/ha compared with supplementing of the CROPWAT generated depth (100%) during mid stage (supplementary of 226.5mm seasonal water) at 8 days interval. This research finding recommended that supplementary irrigation starting from Development Stage (20 days after sowing) is better during development and mid season Stage at 8 days interval.

Key words: Supplementary Irrigation, Irrigation requirement, Irrigation schedule, CROPWAT

Introduction

The Ethiopian economy is based on agriculture. It is also the source of income for about 80% of the labor force in Ethiopia (Bewket and Conway, 2007). Natural rainfall is the major source of water for agriculture. Assessing seasonal or dekadall rainfall characteristics based on past records is essential to evaluate drought risk and to contribute to development of drought mitigation strategies such as supplementary irrigation. Rainfall variability has been reported to have significant effect on the country's economy and food production for the last three decades. There have been reports of rainfall variability and drought associated food shortages (Tilahun, 1999; Bewket and Conway, 2007). In most cases, what determines crop production in semiarid areas of Africa is the distribution rather than the total amount of rainfall, because dry spells strongly depress the yield (Barron et al., 2003; Segele and Lamb, 2005; Meze-Hausken, 2004).Water scarcity is a characteristic of Northern Ethiopia, such as North - Eastern Amhara, particularly in Kobo Girana Valley water scarcity is sever. Due to these; moisture stress is the major limiting factor for crop production which highly reduces the crop yield in the moisture stressed areas. Sorghum is an important food cereal crop used and the major produce crop in rain fed agriculture in the Easter Amhara Region particularly in Kobo Girana valley, where rainfall is not only low or not enough for production but also variable, it begins later and ceases earlier. It stops for certain days in the growing period as major contributor for yield reduction. As a result of such problems, farmers have been continuously affecting with sever grain yield shortage through their traditional agricultural practices.

As the Amhara Regional State Government is emphasizing on developing irrigation-based agriculture to attain food security at household and State levels, it is important that appropriate technologies are available for adoption by the farmers.

One of the approaches taken as a counter measure to the unpredictability of rain and to overcoming such problems is using Supplementary Irrigation during the rain fed agriculture season. Supplemental irrigation (SI) is a highly efficient option to achieve this strategic goal by providing the crop with the needed amount of water at the required time (Oweis and Hachum, 2001). Supplemental irrigation is defined as "the addition of a limited amount of water to otherwise rainfed crops, when rainfall fails to provide essential moisture for normal plant growth, in order to improve and stabilize productivity". Unlike in full irrigation, the timing and amount of SI cannot be determined in advance, because the basic source of water to rainfed crops is rainfall, which is variable in amount and distribution and difficult to predict (Oweis et al., 1999). Alleviating soil moisture stress during the critical crop growth stages is the key to improved production. It was concluded by many authors that avoiding drought, through early flowering and maturity, was the main factor underlying higher seed yield under severe drought conditions.

In this area supplementary irrigation (**SI**) is necessary for the increment of sorghum grain yield & enhancement of food security. Therefore, the research was proposed to quantify and set both the required net Irrigation requirement (depth of water) to be supplemented in the moisture stress period and the time of water application (irrigation schedule) during the rain fed agriculture and to increase water value and crop productivity.

Materials & Methods

The experiment was carried out over two cropping seasons (2011 to 2012) at Kobo agricultural irrigation main research station at Kobo District, in North Eastern Amhara (12.08^0 N (latitude), 39.28^0 E longitudes and at an altitude of 1470 m.a.s.l. Mean annual rainfall in the area is 630 mm, with considerable year-to-year variation. Such rain fall variation results in a range of conditions under which the use of SI is a useful option with which to improve and stabilize yields. There was an average effective rain fall of 232.4mm in the growing season. But this amount of rain fall didn't full fill the crop water demand in the growing season. The soil type in the experimental site is silty clay loam with average FC and PWP of 17.57% and 12.3% on volume basis accordingly. The site is characterized by average infiltration rate of 8 mm/hr and pH value of 7.8.

Sorghum (Teshale Variety) has a growing period of 120days used as a test crop. Fertilizer rate DAP 100kg/ha at planting and urea fertilizer 111kg/ha (36 at planting and 75 at knee height) was added. The experiment was laid out in simple RCBD design in three replications with experimental plot size 3m by 6m. Totally six treatments were tested in the 1st year while in the second year including one treatment added, user adjusted, seven treatments were examined. C-controlled (treatment under rain fed condition no supplementary irrigation. Five supplementary irrigation levels (S1-S5) in different growing stages were determined through using CROPWAT 8 soft ware program and U-daily user adjusted treatment. Irrigation water was applied to the treatments using siphon tubes in furrow irrigation system, which was equipped with time duration to measure the amount of water applied in each furrow.

Table 1: The supplemental treatments in the experimental area

S.no	Treatments	Total crop water requirement (mm/season)	Effective rain fall (mm/season)	Seasonal irrigation requirements (mm/season)
1	Controlled (rain fed farming) (C)	232.4	232.4	0
2	Supplementing the CROPWAT generated depth (100%) starting from DSt (S1)	658.70	232.4	330.6
3	Supplementing the CROPWAT generated depth (100%) starting from DSt at 8 days interval (S2)	563	232.4	426.3
4	Supplementing the CROPWAT generated depth (100%) starting from MSt at 8 days interval (S3)	536	232.4	316.2
5	Supplementing the CROPWAT generated depth (100%) during DSt & MSt at 8 days interval (S4)	548	232.4	304.2
6	Supplementing the CROPWAT generated depth (100%) during MSt at 8 days interval (S5)	458	232.4	226.5
7	User adjustment (U)	417.7	206	211.7

GDP	Gross Domestic Product
GFDRE	Government of the Federal Democratic Republic of Ethiopia
GoE	Government of Ethiopia
GTP	Growth and Transformation Plan
GVP	Gross Value of Production
HACCP	Hazard Analysis and Critical Control Point
HEIs	Higher Education institutions
HR	Human Resource
HRD	Human Resource Development
ICT	Information Communication Technology
ID	Industrial Development
IDSP	Industrial Development Strategic Plan
IFAD	International Fund for Agriculture Development
ILRI	International Livestock Research Institute
IPAP	Industrial Policy Action Plan
ISO	International Standard Organization
ISSP	Industrial Strategy Study Process
LDMP	Livestock Development Master Plan
LIDI	Leather Industry Development Institute
LMA	Livestock Marketing Authority
LMD	Livestock Market Development
LMIS	Livestock Market Information System
MDGs	Millennium Development Goals
MENA	Middle East & North African
METEC	Metals and Engineering Corporation
MFI	Micro Finance Institutions
MIDI	Metal Industry Development Institute
MLEs	Medium and Large Enterprises
MoA	Ministry of Agriculture
MoC	Ministry of Communication
MoCS	Ministry of Civil Service
MoE	Ministry of Education
MoFA	Ministry of Foreign Affairs
MoFED	Ministry of Finance and Economic Development
MoH	Ministry of Health
MoI	Ministry of Industry
MoM	Ministry of Mining
MoST	Ministry of Science and Technology
MoT	Ministry of Trade
MoUDHC	Ministry of Urban Development, Housing and construction
MoWE	Ministry of Water and Energy
MSE	Micro and Small Scale Enterprise
NAIC	National Artificial Insemination Centre
NAMLITS	Namibian Livestock Identification and Traceability System
NBE	National Bank of Ethiopia
NGOs	Non-Governmental Organizations
NIPF	National Industrial Plan Framework
NLDP	National Livestock Development Project
NVI	National Veterinary Institute
OECD- FAO	Organization of Economic Cooperation and Development
OIE	Office International Des Epizootics

PA	Peasant Association
PASDEP	Plan for Accelerated Sustainable Development and Eradicating Poverty
PESTLE	Political , Economic , social Technological, Legal and Economics
PPP	Public Private Partnership
PPPE	Performance of Public Private Enterprise
QSAE	Quality and Standards Authority of Ethiopia
RI	Research Institutes
R&D	Research & Development
REMSEDA	Regional Medium and Small Enterprise Development Agency
S&TU	Science and Technology Universities
SACU	South African Customs Union
SDDP	Smallholder Dairy Development Project
SDPRP	Sustainable Development and Poverty Reduction Program
SLOT	Strength, Limitation, Opportunity and Threats
SMEs	Small and Micro Enterprises
SNNPR	South Nations Nationalities Peoples Region
SOC	Social Overhead Capital
SOEs	State Owned Enterprises
SPS	Sanitary and Phytosanitary
STII	Science Technology and Innovation Institute
SWOT	Strength, Weakness, Opportunity, Threat
TIDI	Textile Industry Development Institute
TVET	Technical and Vocational Education and Training
UAE	United Arab Emirates
USA	United States of America International Development
USAID	United States Agency for International Development
USD	United States Dollar
VAT	Value Added Tax
VDFACA	Veterinary Drugs , Feed Administration and Control Authority
WHO	World Health Organization
WTO	World Trade Organization

Water productivity, also known as water use efficiency, was determined as the ratio of crop yield per unit area, in terms of grain, to crop evapotranspiration (mm), and was expressed as kg of grain or biomass per m3 of consumed (evapotranspired) water. Statistical analysis of the data included analysis of variance (ANOVA), using the SAS software, to test the effects that season, SI had on grain yield, stalk biomass, and water productivity.

Result and Discussion

Distinguish that year -to -year variations occurred in treatment effects (Table 2). Even though the actual rainfall amount occurred in the second year was less than the long term mean value, more amount existed at initial stage affects the growth performance and became stunted growth. Furthermore the grain yield and yield components in the second year were highly affected by the occurrence of stalk boarer disease at development stage.

Table 2: Analysis of variance

Source of variation	Degree of freedom	Mean square		
		Grain yield	Stalk biomass	Water productivity
Replication	2	0.7818	1.138	0.0271
Treatment	5	1.2255	3.664*	0.0958**
Year	1	59.6017**	126.875**	2.4701**
Treatment*year	5	0.4915	1.165	0.0196
Error	33	0.48	1.105	0.0196

The combined analysis of variance for both years showed that there was none significant interaction effect between treatments across years on grain yield, stalk biomass and water productivity. For detailed observation the combined and individual year results of treatments indicated below (Table 3).

The experimental analysis indicated that there was a significant difference in stalk biomass, grain yield and water productivity in the first year. Sorghum grain yield, biomass yield and water productivity were highly decreased in the second year, with the adverse effect of high rain in the initiation stage and disease infestation. However grain yield, stalk biomass and water productivity showed statistically significant different. As observed in the experimental years the grain yield widely ranges from 5.397ton/ha to 1.53ton/ha.

Supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application gave the highest stalk biomass of 11 ton/ha and grain yield 5.397ton/ha and it had a maximum yield advantage 2.874 ton/ha compared with the controlled system in 2011 cropping season. Sorghum yield under rain fed condition (control treatment) consistently had low yield in both experimental seasons. The production potential of the crop was extremely affected by rainfall amount and distribution conditions. Combined result of the

two years cropping season showed that stalk biomass and water productivity were statistically significant, but grain yield didn't.

In water productivity supplementing the CROPWAT generated depth (100%) during MSt.(mid stage supplementary of 226.5mm seasonal irrigation water) at 8 days interval had a maximum value of 1.957kg/m^3. But the other treatments had non-significant difference in water productivity, except the control treatment. And also supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application with a seasonal water amount of 330.6mm had a yield advantage of 1.607ton/ha compared with supplementing of the CROPWAT generated depth (100%) during MSt (mid stage supplementary of 226.5mm seasonal water) at 8 days interval in the first production season.

Water productivity was about 0.96 kg of wheat grain m−3 of water under rainfed conditions and 1.36 kg of wheat grain m−3 under supplemental irrigation (Zhang and Oweis, 1999). two years cropping season showed that stalk biomass and water productivity were statistically significant, but grain yield didn't.

In water productivity supplementing the CROPWAT generated depth (100%) during MSt.(mid stage supplementary of 226.5mm seasonal irrigation water) at 8 days interval had a maximum value of 1.957kg/m^3. But the other treatments had non-significant difference in water productivity, except the control treatment. And also supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application with a seasonal water amount of 330.6mm had a yield advantage of 1.607ton/ha compared with supplementing of the CROPWAT generated depth (100%) during MSt

(mid stage supplementary of 226.5mm seasonal water) at 8 days interval in the first production season.

Water productivity was about 0.96 kg of wheat grain m−3 of water under rainfed conditions and 1.36 kg of wheat grain m−3 under supplemental irrigation (Zhang and Oweis, 1999).

Table 3: Mean separation result of plant height, stalk biomass, pure grain yield and water productivity

S. no	Treatments	First year [illegible]			Second year [illegible]			combined		
		Stalk biomass (ton/ha)	Pure grain yield (ton/ha)	water productivity (kg/m3)	Stalk biomass (ton/ha)	Pure grain yield (ton/ha)	water productivity (kg/m3)	Stalk biomass (ton/ha)	Pure grain yield (ton/ha)	water productivity (kg/m3)
1	C	[illegible]	[illegible]	[illegible]	[illegible]	1.3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	11a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	U	-	-	-	[illegible]	[illegible]	[illegible]	-	-	-
	Cv (%)	[illegible]	8.2	11.8	[illegible]	24.6	30.6	[illegible]	25	34.2
	Lsd	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Grand mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The same letters are not significantly different (P<0.05), ** significant (p=0.01) & * significant (p<0.05) according to a Duncan's multiple range test.
Note: GD= generated depth, DSt=development stage, LSt= late stage, OPT= optimum Time of application MSt=mid stage

Conclusion and Recommendation

Supplemental irrigation is a feasible option that can be used by farmers in the Kobo area to increase and stabilize their rain fed sorghum production. The application of supplemental irrigation can also help the crop escape critical stages particularly terminal drought or moisture stress. As a result areas like kobo which have problems of rain fall distribution and occurrence (late on set and early off set) and accesses to irrigation can increased their yield by supplementing irrigation starting from crop development stages.

However, in rain fed areas comes at a cost. Therefore, economic studies are highly recommended in order to evaluate its feasibility and to identify any constraints that might affect its implementation .

Acknowledgements

The authors would like to give their deep gratitude's to Mr. Seid Belay and Gebayew Molla for the support of them provided with regard to field work from initial to final of this experiment.

References

Barron, J., Rockstrom, J., Gichuki, F., Hatibu, N., 2003. Dry spell analysis and maize yields for two semi-arid locations in East Africa. Agric For. Meteorol. 117, 23–37.

Bewket, W., Conway, D., 2007. A note on the temporal and spatial variability of rainfall in thedrought-prone Amhara region of Ethiopia. Int. J. Clim. 27, 1467–1477.

Oweis, T., Hachum, A., Kijne, J., 1999. Water harvesting and supplemental irrigation for improved water use efficiency in dry areas. SWIM Paper No. 7, System-Wide Initiative on Water Management. International Water Management Institute (IWMI), Colombo, Sri Lanka.

Segele, Z.T., Lamb, P.J., 2005. Characterization and variability of Kiremt rainy season over Ethiopia. Meteorol. Atmos. Phys. 89, 153–180.

Tilahun, K., 1999. Test of homogeneity, frequency analysis of rainfall data and estimate of drought probabilities in Diredawa, eastern Ethiopia. Ethiopian J. Nat. Resour. 1, 125–136

Zhang, H., Pala, M., Oweis, T., Harris, H.C., 2000. Water use and water use efficiency of chickpea and lentil in a Mediterranean environment. Aust. J. Agric. Res. 51, 295–304.