

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES



**AGRICULTURAL WATER MANAGEMENT MODELING AND ANALYSIS UNDER
CLIMATE CHANGE AND LAND TRANSFORMATION
(A CASE STUDY OF LOWER OMO GHIBE BASIN)**

Part I: Evaluation of Performance of SWAP and CROPWAT model simulating irrigation water requirement on Sugarcane Yield of Kuraz Irrigation Project

A Thesis Submitted and Presented to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Degree of Masters of Science in Civil and Environmental Engineering under the Stream of Hydraulic Engineering.

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Addis Ababa, Ethiopia
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BY

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APPROVAL BY BOARD OF EXAMINERS

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External Examiner	Signature	Date

CERTIFICATION

I, the undersigned, certify that I read and hear by recommend for acceptance by Addis Ababa institute of Technology a thesis entitled **Agricultural Water Management Modeling and Analysis Under Climate Change and Land Transformation (A Case Study Of Lower Omo Gibe Basin) Part I: Evaluation of Performance of SWAP and CROPWAT model simulating irrigation water requirement on Sugarcane Yield of Kuraz Irrigation Project** in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (major Hydraulic Engineering).

Dr. Daneal F/Selassie
(Supervisor)

Date

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Finally, all the gratitude and honor I give them to my Lord.

Abstract

Human activities and climate factors both affect the availability of water resources and the sustainability of water management and that in turn affect agricultural water management especially in already dry regions, water has become scarcer with increasing requirements from growing population, economic development. Although progress has been made in understanding variability of runoff, the impacts of climate variability and human activities on agricultural water management (actual evapotranspiration) and (discharge accumulated in the river network) remain less well understood.

South omo Gibe basin which is one of the sub basin in Ethiopia has suitable land water resource for agriculture for both farm and livestock and currently huge investment are found on irrigation project, and from these the dominant is state owned irrigation like kuraz sugar development irrigation project in the sub basin which planned to irrigate sugarcane on 175,000 hectare of land. According to works design and supervision enterprise that prepare design document of the project the water requirement of the plant is modeled with cropwat considering only atmospheric water demand and put the yield in figure in its report.

However now a time In south Omo Gibe sun basin a frequent happening of high and low rainfall, less work on soil conservation practice and deforestation are observed as causes of changing of climate and land degradation that make the need for improved and resilient agricultural water management to have greater yield of the crop with environmental sustainability and so efforts towards improved and resilient agricultural water management is must.

Therefore, the main objective of the research presented here is to study the effect of climate change specifically drought and land degradation on water demand and crop yield in the area of study and compare the existing crop oriented model used for the design of crop water requirement of the crop in the project area with agro hydrological model for better irrigation management under climate change and land transformation. To achieve this purpose, an available code that takes into account the interaction between soil, water, atmosphere and plants SWAP model is used after assessing the challenges in the sub basin and identifying adaptation strategy for improved agricultural water management and compared with Cropwat model. consequently, it is tried to analyze the impact of future climate changes and land transformation water demand for irrigation and relative crop yield in the Kuraz irrigation project area.

From the result of the performance of the two model SWAP model result of actual evapotranspiration and irrigation water requirement is greater than the designed crop water requirement of cropwat model output which can be calibrated with yield of sugarcane. And the comparison of the two models shows that SWAP model output indicate the actual evapotranpiration and irrigation water requirement is greater than the CROPWAT model output

of the designed irrigation water requirement that can make conform with yield reduction of sugarcane the in project area as a calibration method due to shortage of data.

Even though the reduction of sugarcane is happen due to technical inefficiency as I can get the result of research paper on irrigation management practices in kuraz irrigation project, climate change and land degradation plays large effect in this technical inefficiency of irrigation water management more than different tillage practices. in this research due to shortage of data to measure soil moisture and ground water data in the project area I used the yield reduction data from analysis of technical efficiency sugarcane production.

From this result neglecting other factors that decrease the yield of sugarcane and considering the effect of climate change and land degradation only, it shows the need of irrigation water will be high to maintain good yield of sugarcane in the future. Today, the sugar corporation supplies 300 m³/sec which is the minimum release discharge from Gibe III hydropower project. This means that the corporation should focus on works that increase the amount of water for irrigation in the future.

Consequently, taking into account all the simplification and the uncertainties in the model, it is safer for the corporation to increase the water supply capability in the future, particularly using a better approach of soil and water management integrated with sub basin scale soil and water conservation practices should be followed, in order to cope the increasing water demand in the future.

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List of Abbreviations

CGCM	Climate Global Circulation Model
CH	Crop Height
CPRO-DLO	Central for Plant Breeding and reproduction research
DVS	Development Stage
EPIC	Erosion productivity Impact Calculator
ET	Evapotranspiration
Eta	Actual Evapotranspiration
ETp	Potential Evapotranspiration
FAO	Food and Agricultural organization
GIS	Geographical Information system
IPCC	Inter Panel of Climate Change
ITCZ	Inter tropical convergent zone
Ky	Yield Response Factor
LAI	Leaf Area Index
RCM	Regional Climate Model
RDens	Root Density
RDepth	Root Depth
SWAP	Soil Water Plant Atmosphere
SWAT	Soil and water Assessment Tool
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Tp	Potential Transpiration

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1 Introduction

1.1 Background

Agricultural water management includes many topics: farm-level and regional water management, irrigation, drainage, and salinity management of cultivated areas, collection and storage of rainfall in relation to soil properties and vegetation; the role of groundwater and surface water in nutrient cycling, exploitation and protection of water resources, control of flooding, erosion, and desertification.

Agriculture is critical to development - the majority of the world's poorest and hungry people depend on it for their livelihoods. Agriculture in turn depends on basic natural resources: biodiversity, soil, and water. Good stewardship of natural resources is central to sustainable development: agriculture's long-term viability is a function of how well we - individuals and communities - fulfill our roles as stewards.

Globally, there are high expectations for the potential of improved agricultural water management to drive agricultural growth and poverty reduction (Mollinga et al., 2007). These expectations are understandable; the regions where there are high levels of poverty and stunting coincide with those characterized by drought, soil nutrient depletion and land degradation (Leakey et al., 2009) where there is a high probability of drought affecting large areas of cultivation (Hyman et al., 2008). The millions of people whose livelihoods and nutritional status depend on these major agricultural systems provide a glimpse of the extensive impact that improved agricultural water management, including the promotion of improved varieties and agricultural system diversity, could have on food security. In Africa alone there are more than 33 million small-scale farming households (Nagayets, 2005) where the sustainable and productive management of water could contribute to transforming degraded soils and landscapes into healthy agro ecosystems capable of enhancing food security, improving livelihoods, and increasing resilience to climate change and variability.

But this is small compared with the high potential of water and land of the sub basin and still much of the availability of land and water shows high potential of the sub basin for economic development. For the case study part, reviewing all available official data after my field visit to collect secondary data from concerned offices, I decided to use, most of the meteorological data from Kuraz sugar development project feasibility study design report prepared by water works design and supervision enterprise, because of the poor data availability both from National meteorological agency and ministry of water and irrigation. In addition, even the data set from remote sensing product is also available online, using these data after testing and correcting with the gauging station data make this paper bulky. With this concept, I was able

to use kuraz project design report hydrological and meteorological data for this model and to achieve a spatial and area-wide picture.

According to climate change assessments, less precipitations and higher temperatures can be expected in south Omo Gibe sub basin. Besides, an increment in droughts studies shows high land degradation and nutrient depletion of agricultural land as well. Such climatic and land conditions require an effort to improve agricultural water management efficiency and to optimize irrigation technologies. There are currently available water-use and crop-growth simulation models, which can be combined to climate and land use scenarios in order to recommend through many simulations, the most reliable irrigation management. The analysis and modeling of Agricultural water supply and demand under climate change and land transformation of fast growing environment that experienced significant climate change and land use over the last few decades are challenging in the sub basin.

Consequently, to overcome these challenge the input data for modeling climate and land use changes scenario in the area should be periodical, mostly daily basis and both the climate and land parameter data need to be estimated using different methods to forecast their effect on agricultural water management. Consequently Sugar Corporation would to know the demand of water for irrigation in the area of Kuraz sugar development project in response to future climate change and land transformation in order to ensure optimum crop yield. Beside this the corporation also need further researches for effective agricultural water management including effective fertilization management, nutrient management and solute transport .The research presented here tried to answer the need of sugar corporation for water demand in the Kuraz project area modeling the water transport specifically excluding solute transport due to shortage of data as a case study.

According to the design report of kuraz sugar development project prepared by WWDSE the water balance modeling was done in order to check the capacity of Omo river in respect to satisfying the water requirement of kuraz irrigation project and maintain the channel flow downstream of diversion. Accordingly the result of analysis showed that without Gibe III operation the Omo river doesn't satisfy the irrigation demand for some months.

Consequently, this implies optimum using the water for irrigation and conserving the sustainability of the river amount of water is must despite of most of the research shows the increase of temperature and land degradation will both increase the crop water requirement in the future.

From the research done on Omo gibe basin higher emission scenario the basin will face drought condition and due to increased temperature the evaporation condition of the basin will be high The current mean annual maximum and minimum temperature is expected to rise by

about from 0.9 0c to 1.80c and 1.20c to 2.2 0c as the result for 2 0c raise in mean annual surface air temperature is expected in the future

Research on land use and cover change on stream flow shows the surface runoff was increase by 87.475 m³/s in the wet season and decrease by 25.66 m³/s in the dry season from 1987 land use land cover to 2013 land use land cover and having this data it is tried to project for the future having the data of the above research and correlating accordingly. Also sedimentation effect will be high in decreasing the amount and head of water supplied for irrigation, for example if we see the design discharge of kuraz right side block main canal design discharge it is 165 m³/s and need to calculate how much this design discharge will be affected by decrease of the amount of river and increase of sedimentation.so first let see the effect of sedimentation and then we will estimate how much water decrease in the canal.

The correlation between inflow sediment yield in order to estimate the probable magnitude of the sediment yield for the kuraz catchment linear regression analysis of most of Ethiopian catchment shows a quite good agreement between the two variables the correlation coefficient is 0.8 the obtained equation is $Y=8*10^{-5}X^{1/3}$ from these equation we get and having this projected data this paper tries to show the effect future climate increase and decrease of the amount and head of the river on the yield of sugarcane in the project area.

Water works design and supervision enterprise also put some points in the design report that need further research for effective agricultural water management in the design report, some points including stabilization on the cane cycle study on fertilizer type rate and application method, management of irrigation application, determination of appropriate dry off period for plant cane and ratoon on different soil type management of sodic soil and saline soils, drainage improvement and erosion control measure.

Consequently the need for improved irrigation water management according to the recommendation of water works design and supervision enterprise to mitigate the above mentioned changes and their effect is expected. And these changes in climate change and land transformation makes the use of different model that simulate the actual water requirement considering climate and land change effect in to account and compare with the existing irrigation water management model to check the accuracy. Even though it is possible to simulate and calibrate with different factors and parameter taking into consideration for improved irrigation management, in this paper i tried to compare the two irrigation models the common agro hydrological model SWAP and the current existing model in project area cropwat on evapotranspiration and irrigation requirement and then show the performances of the models on actual irrigation requirement based on the yield of sugarcane on kuraz irrigation project as calibration in order to show the effect of climate change and land degradation effect on the product of sugar.

1.2 Problem statement

Water resource management in agriculture is a critical contributor to the economic and social development of Ethiopia and, if successful, irrigation in Ethiopia could represent a cornerstone of the agricultural development of the country, there are high expectations for the potential of improved water management to drive agricultural growth and poverty reduction. These expectations are understandable; the regions include major farming systems like Lower Omo Gibe basin. the study research area, which is characterized by its arid and semiarid climate and lower elevation geographic area, there is a high probability of drought occurrence due to temperature increase and soil nutrient depletion due to land degradation caused by human induced factor and climate change.

IPCC findings indicate that developing countries such as Ethiopia will be more vulnerable to climate change, and climate change may have far reaching implications for Ethiopia because of its economic, climatic and geographic settings. The country has a fragile highland ecosystem that is currently under stress due to still increasing population pressure like the upper Omo Gibe basin. In addition to climate change, land use will continue to evolve in a watershed, and may affect water quality.

Different researches shows that in Ethiopia the design study focuses mainly on crop oriented model like Kuraz sugar development irrigation project feasibility study design report used model and these result in Low-performing schemes and less irrigation development sustainability. Scheme sustainability demands an ambitious program for groundwater resource research and regulation, and integrating watershed and environmental management across all irrigation development and these bring the need for improved agricultural water management.

The main purpose of an irrigation system is to maximize crop production to improve economic growth and alleviate the hunger and poverty in the country. Therefore, water needs to be distributed efficiently, for the crops at the right time with an effective quantity. Efficient water allocation for crops can result in saving water, increasing the cultivated land area to some more extent, or else in using that amount of saved water for other economic and social purposes such as domestic and industrial use. In order to optimize water use and crop productivity, one has to improve the water resource allocation optimally in a water limiting condition region (arid and semi arid), improve irrigation scheduling, and establish crop water needs, which are influenced by the rate of water used with the crops, evapotranspiration (ET) and other losses such as soil retention characteristic. Therefore, a study is needed to address the problems as to how to make the best use of limited water available, while maximizing economic return to water use. This requires evaluation of crop water requirement, irrigation water requirement, irrigation scheduling, cropping system and crop Therefore, a study is needed to address the problems as to how to make the best use of limited water available, while maximizing economic return to water use. This requires evaluation of crop water

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Therefore, a study is needed to address the problems as to how to make the best use of limited water available, while maximizing economic return to water use. This requires evaluation of crop water requirement, irrigation water requirement, irrigation scheduling, cropping system and crop budget.

The investment in this area is mainly designed with crop oriented model and this model does not consider the effect of soil texture, however soil interacts with water and therefore its characteristics are a reflection of, and sometimes the reason for agronomical decisions. However, in some areas of the country the information on soil and the effects of the irrigation techniques over them is scarce. The root water absorption in crop oriented model is calculated using a law of the limiting approach whereby the soil resistance, the root resistance, or the atmospheric demand dominates the flow rate of water into the roots. The flow rates are calculated using assumptions of water movement to a single root and that the roots are uniformly distributed within a layer, since the cascade approach is unable to simulate upward water movement due to capillary rising, crop oriented model yield predictions significantly depart from actual yields under heavy rain conditions.

1.3 Objective of the research

The overall objective of this study is to investigate cropping system and water use options to improve irrigation water allocation and use in context of climate change and land degradation, on a case study basis evaluating the performance of two models SWAP and CROPWAT. The specific objectives include:

- Assessment of crop water requirement in the case study area for sugarcane crop and identifying impact on irrigation efficiency due to increase of temperature and decrease of water level in the canal on crop water requirement.
- Quantifying and predicting current field condition effect on increase of temperature and decrease of water level in the canal effect using SWAP model and also simulate the same cropped field using CROPWAT model.
- Compare the performances of the two models in predicting actual crop water needs on crop water requirement and yield of sugarcane to give recommendations for irrigation practice on the usefulness of Agro hydrological model.

1.4 Rationale of the Study

The Ethiopian government plan emphasizes the development of irrigation systems through giving highest priority for modernizing the system in the study, design, and implementation of irrigation projects. In recent years it have seen significant progress in addressing the delivery of irrigation schemes, but have also underscored the persistence of some fundamental challenges. Specifically, primary rationales for developing the irrigation sector in the sub basin include

Ethiopia's crop productivity is frequently below potential. The average yield of crops is less than the potential yield. Increasing farmer productivity is a crucial lever to improving smallholder income and livelihood. Irrigation helps improve crop productivity, especially when used in conjunction with improved inputs (e.g., seed, fertilizer).

Climate variability is expected to increase the occurrence and the severity of extreme events (flood and drought) and related shocks. And also the sub basin soil is estimated to be moderately to severely degraded, which decreases the productivity of land and negatively affects water and land resources and agricultural productivity; salinity and water logging or leaching is already an issue in some large-scale irrigation like kuraz sugar development irrigation project.

However Irrigation application in Ethiopia and in our case study area is based on crop oriented model or recalling the last irrigation applied to the field and this agriculture practice of the area does not have tool to simulate mitigation strategy for climate change and Land transformation using and soil moisture and ground water level data so that it cannot be quantified how much effect it has on crop yield. And the irrigation scheduling techniques are still mainly based on availability of maximum quantity of water which a farmer can get. Hence present irrigation patterns of farmers include a tendency to over irrigate or giving extreme shortage, which cause the insufficient situation for the crops.

To address the solution for improvement in water availability and value of the issue, this research study is focused on the improving of irrigation water allocation and use comparing crop oriented model CROPWAT with agro hydrological model SWAP. Accordingly recommendation in context of south omo gibe basin, irrigation water management for a sound use is the primary issue has to be matter of concern. This study help for more beneficial planning based on maximum water saving to expand irrigation area.

Research works on the use of agro-hydrological models have been conducted in Asia, Europe, U.S, few African countries .However, studies on the application of these models in water management in Ethiopia, and in particular the study area is yet to be fully explored. This when accomplished might serve as water management tool for the various farming activities available in the country. Use of simulation reduces drudgery and time wasting in field

experimentation to establish a water management option. It can also serve for research purposes by the university community. The knowledge of soil water balance is very vital under crop water management strategy and having a model that can simulate the soil water balance, as against the tedious direct methods is an added advantage.

1.5 Description of the Study Area

1.5.1 Location and description of Omo Gibe basin

The Omo-Gibe basin is one of the major river basins in Ethiopia and is situated in the south western part of the country covering parts of Southern Nations, Nationalities and Peoples Region (SNNPR) and Oromia region. The basin covers an area of 79,000 km² with a length of 550 km and an average width of 140 km. The basin lies between 4000'N & 9022'N latitude and between 34044'E & 38024'E longitude. It is an enclosed river basin that flows in to the Lake Turkana which forms its southern boundary. The totals mean annual flow from the river basin is estimated about 16.6 BMC

Omo Gibe watershed is selected as case study for this research because large scale and medium scale irrigation potential are identified in the basin, with an estimated irrigable area of 57,900 and 10,028 hectares respectively, and a total irrigable area of 67,928 hectares. However, this figure could be much higher given the vast land area of lower Omo. In addition, it can be considered as representative watershed where there is high landscape and climatic zone difference within short distances. The population growth and land use systems together with considerable human interventions in the upper part of Omo watershed makes it feasible for climate change and land degradation impact analysis on hydrological regime.

The Omo River is one of the largest rivers in Ethiopia with mean annual flow of the river reaching up to 20 BMC and with catchment area of 79 000 km². The River is thus a vital natural resource of the country. As per the Omo Gibe Master Plan Study, even though many areas in the basin are not suitable for irrigation development, either due to steep slope or soil, the lower Omo area where the project is to be constructed, has extensive plains, moderately suitable soils and sufficient water available from Omo River. Overall about 175 000 ha net potential irrigable area is delineated for sugar cane development in the right and left bank of lower Omo Sub-Basin.

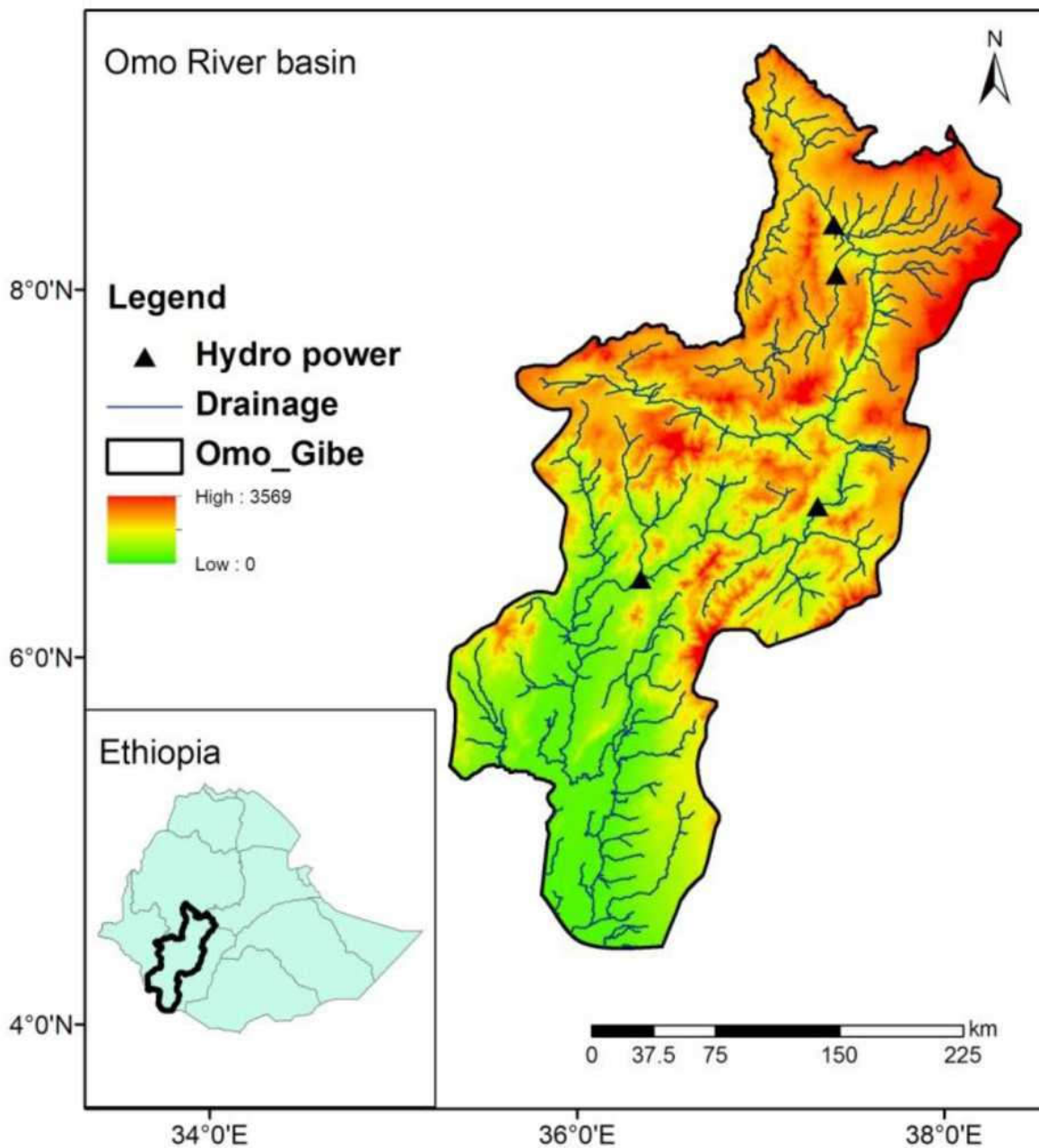


Figure 1 Omo Gibe River Basin

1.5.2 Climate of the study area

Omo Gibe River Basin has three distinct climate zones across the watershed in which it follows the country's climate classification, namely, Dega (cool zone), Weyna-Dega (temperate zone) and Kolla (hot zone). The highlands that comprise the areas around Jima and around the headwaters of the Gojeb River are classifiable as tropical humid climate. For the largest proportion of the watershed is classifiable as a tropical sub-humid i.e., intermediate

between the tropical humid and the hot. The rest southernmost part of the floodplain toward Lake Turkana has the characteristic of hot arid climate³. The seasonal variation in climate is due to the oscillation of the Inter-Tropical Convergence Zone (ITCZ)⁴. ITCZ shifts during the year northwards across southern Ethiopia from September to November and southwards from March to May, giving origin to the alternation of a wet (from June to September) and a dry (from December to April) season.

(i) Rainfall

Rainfall in Omo-Gibe basin varies from over 1900 mm per annum in the north central areas to less than 300mm per annum in the south. The amount of rainfall decreases throughout the Omo-Gibe catchments with a decrease in elevation. Moreover, the rainfall regime is unimodal for the northern and central parts of the basin and bimodal for south.

During these two the dry season is long, which is favorable for dry off and ripening of the cane to be harvested; it also means that during the long dry season irrigation is needed for the growing cane in order to satisfy the cane's water requirements. It also indicates that, unless unexpected heavy rain occurred and created water logging, field activities (land preparation) could be carried out throughout the year except at the months of April and May in which the rain is relatively high.

Sugar cane germination is optimum between 26°C and 33°C and minimum under 18°C. During night time germination is always under good temperature conditions, but it is at the maximum during day time. So unless water logging of heavy soils occur during the rainy seasons, planting can be carried out throughout the year.

Principal climatic components that control cane growth, yield and quality are temperature, light and moisture availability. The plant thrives best in tropical hot sunny areas. The "ideal" climate for production of maximum sugar from sugarcane is characterized as:

A long, warm growing season with a high incidence of solar radiation and adequate moisture (rainfall) and a fairly dry, sunny and cool, but frost free season for ripening and harvesting season. Growth is optimum between 30°C and 33°C and slows down fewer than 20°C. The temperature of Kuraz area is ideal for sugarcane growth.

Sunshine duration and intensity directly influence photosynthesis in all plants and thus ultimately control the growth. The light requirement of sugar cane is relatively higher than that of all other grain crop except rice. It has been established that 8 hours sunshine per day is good for sugar cane. At Kuraz, all month have more 8 hours of sunshine except in May, July and August.

(ii) Temperature

The mean annual temperature in Omo-Gibe basin varies from 160C in the highlands of the north to over 300C in the lowlands of the south. The maximum temperature is higher at the southern part of the basin especially at Morka mean annual maximum temperature reaches up to 30.6 0C. There is a little variation in minimum temperature which varies from 9.20C in northern part of the basin example in Gedo to 160C in southern part of the basin at Jinka.

Regarding Kuraz sugar project, according to the Climatology and Hydrology Study report of the project, there is no single weather station to represent the command area to collect relevant climatic data. So that different sources, especially neighboring stations are used as a source. The data in this report are direct copy of the stated report.

According to the report, the rainfall ranges from over 1 900 mm/year in the northern and western part of the basin to less than 300 mm/year near Lake Turkana. The command area annual rainfall is in the range of 661.4 mm with 75 %, 80 % and 90 % dependability of 256, 214 and 159 mm, respectively.

Temperature over the project area varies from 190C (July and August) to 330C (February), Wind speed from 10.4 km/h to 15.5 km/h, humidity from 57 % to 75 %, sunshine hours from 6.9 hrs to 10.2 hrs. The mean monthly evapo-transpiration values ranges from 151mm to 205 mm with annual value of 2 070 mm. The minimum and maximum temperature as given in, exhibit the monthly maximum and minimum temperatures of 33.10C and 19.10C, respectively. The highest is recorded in the month of February followed by March and January. The minimum is recorded in the month of July, August followed by September.

The average sunshine hour in the area is 8.8 hours. The highest number of hours is 10.2 in February, followed by January and December. The annual average relative humidity is 66.0 %, and the highest of 75 % is experienced in the months of May. The lowest humidity of 57 % is in the month of January. The annual average wind speed is 3.8 m/s with the highest value of 4.3 m/s in February and November. The minimum wind speed has been recorded as 2.9 m/s in April.

1.5.3 Topography and river systems of the basin

The topography of Omo Gibe basin as a whole is characterized by its physical variation. The northern two-thirds of the basin has mountainous to hilly terrain cut by deeply incised gorges of the Omo, Gojeb, and Gilgel-Gibe Rivers, while the southern one-third of the basin is a flat alluvial plain punctuated by hilly areas. The northern and central half of the basin lies at an altitude greater than 1500 masl with maximum elevation of 3360 masl (located between Gilgel- Gibe and Gojeb tributaries), and the plains of the lower Omo lies between 400-500 m asl (Richard Woodroffe & associates Vol VI, 1996).

The project area is located on the fault graben of the southern rift valley along the foot of the western rift escarpment. Its physiographic setting is the result of volcano-tectonic and fluvial processes. Generally, the project area could be characterized by its flat low land and by the surrounding escarpment ridges. Its altitude ranges from 412–468m above sea level, which results in flat land classes in the Berha agro climatic zone. According to the study conducted by WWDSE (2015), the area is dominantly covered by superficial deposits and bedrocks. The superficial deposits include gravel deposits, silty clay deposits and undifferentiated deposits (mixture of colluvium, alluvial and residual soils), while the bedrocks include rhyolite and basaltic rock units.

1.5.4 Soil and Agricultural land use

(i) Soil physical property

More specific soil studies in the basin have concentrated on the irrigation potential of the lower Omo valley with some work on erosion and conservation measures. Poorly drained vertisols are the dominant feature of the land scope in many areas of the upper basin, and common in the plains of lower Omo where they occur in association with poorly drained sodic clays. Alluvial and colluvial soils of lower Omo, these soils are characterized by their highly heterogeneous nature in terms of texture both laterally and vertically. Soil erosion is also serious problem in Gilgel Ghibe watershed. The total soil loss into the Omo River from landslide is estimated as 11 t / ha/ yr for the last 20years

The soil physical characteristics, most of the soils are dominantly marked by the occurrence of four broad textural groups: fine texture (fine clays and silty clays), heavy texture (heavy clays), medium textured (loam, clay loam, silty clay loam and silt loam) and sandy texture (sandy loam). The textural class of the soils at the surface horizons varied from loam to clay/heavy clay, while the sub-surface horizons showed sandy loam to heavy clay texture. In general, most of the soils are deep to very deep with the exception of some soils showing shallow/very shallow depths specifically in miscellaneous land types which are developed on shallow/very shallow stony/rocky beds.

The available water holding capacity of the soils in the project area ranges between 242.1 mm/m to 463.3 mm/m showing the availability of high AWC for irrigation suitability. The majority of the soils in the project area have heavy clay texture (> 60 % clay content) and this might be attributed for the occurrence of high level of AWC. The bulk density of the soils of the project area ranges from 1.59 to 1.89 g/cm³ for 0 - 100 cm soil depth.

The measured infiltration rates of the soils range from 0.3 cm/hr to 0.5 cm/hr which is slow to moderately slow partly in the soils having fine and heavy textures, which is more or less falls within the FAO range of standard. Whilst given the fine/heavy clay texture top soils in some

of the mapping units, the infiltration rates of the soils are surprisingly moderate to moderately slow, ranging between 1.1 and 5.4 cm/hr.

(ii) Soil chemical properties

As far as the chemical properties are concerned, most of the soils are moderately alkaline to very strongly alkaline. The soils are also characterized by the existence of high CEC levels and high base saturation percentage top to sub-soils. In most cases the soils of the command area have low organic carbon content levels and also have low to very low total nitrogen levels. Thus nitrogen must effectively be supplied through appropriate fertilizer application.

The occurrence of low organic carbon and total nitrogen content could be related to high soil alkalinity as well as to climate (semi-arid climate with high temperature) which decreases bacterial activity and hence nitrification of organic matter. Available phosphorus levels are generally medium to high levels. Most of the soils have electrical conductivity (EC_e) of saturated paste values of the soils were below 2.7 mS/m in most cases indicating the soils are non-saline. In general most of the soils of the present study area are characterized by imperfectly drained to poorly drainage classes, whereas the external drainage of the soils found to be slow in most cases. The imperfectly and poorly drained soils are mainly associated with the soils of heavy clay textures and low topographic position with slope ranging between 0.2 - 1 %. Thus, a well-planned drainage system and proper choice of agricultural machinery is essential to manage the soils successfully.

In general the pH values of the soils in the command area ranges between 7 – 9.53. This is throughout the soil horizons indicating the soils are moderately alkaline to very strongly alkaline. The top layers as compared to sub layers the pH is moderately alkaline, but with depth in the sub layers, the soil pH increases and the soils are very strongly alkaline. Generally the levels of CEC and BS % in the identified soils are high to very high and high, which is greater than > 40 meq/100 g soil, may respond to fertilizer application and are suitable for irrigation. The soils have also a base saturation of soils > 60 % indicating high fertility status.

The total nitrogen content on most of the top soil layers is very low and ranges between 0.74 % and 1.9 %. Totally the content of organic matter of the soil of the command area on top and sub layers of the soil layers are is very low. Application of farmyard manure and avoid burning the land during land preparation is suggested to minimize the loss of organic matter. According to the laboratory analysis results of the soil samples in the current project area, mapping units have showed slightly saline to moderately saline properties with EC_e 4 to 11.6 dS/m in their sub-soils. Some of the mapping units are characterized by the presence of ESP >15 % reflecting the existence of sodic soils in their sub-layers. The soils with the ESP values as high can be managed by applying appropriate soil management/amendment practices such

as gypsum application and leaching of the soils after replacing Na by Ca at the exchange complex by gypsum.

1.6 Frame work of the study

Impact studies on climate change require realistic assessments of future climate change at specific regions or locations however, in practice; there are problems of hydrological data like missing data, reliability and ability of the data to represent the hydrological phenomena being considered. Often, the presence of gaps will shorten the records and will render spurious results or misleading conclusions, for example one of the research I referred most, Susy Rita Wanti (2012) Application of SWAP model to analyze the impact of drought and climate change on water demand and apple fruit crop yield in the Kromme Rijn area, used a data obtained from KNMI recorded in De Bilt weather station. KNMI has been collecting meteorological data daily for the last twenty six years (1986-2011) from several weather stations in the Netherlands however in our case south Omo Gibe basin it is difficult to get such data and this problem is more critical for those developing countries, like Ethiopia, and also, though soil physical and hydraulic properties are of prime interest in agro hydrological model soil properties are measured in field at point scale and such data are commonly are unavailable over large areas and have limitation in accounting for region spatial variability and it is prohibitively expensive tedious and time consuming.

However in this paper it is tried only to simulate water movement in the soil and due to the need for monitoring wells for ground water level data and field soil moisture data which is important input data for agro hydrological model like SWAP, lack of information bears limitation in quantifying the trends and status of the water level in the area. So in this paper the model is calibrated and validated only comparing the evapotranspiration of result of SWAP model and cropwat model attenuating with the yield of the sugarcane in kuraz sugar development irrigation project area according to study document which was predicted using cropwat model and other research study on yield reduction due to technical inefficiency in the project area. Consequently in this research I evaluate the performance of the two model SWAP and crop model based on the yield of sugarcane in the project area due to shortage of soil moisture and ground water data.in addition lack of solute nutrient in the soil data and soil heat data, I am unable to simulate their effect using SWAP model for comparison on improved agricultural water management of the area.

2 Literature Review on Agricultural water management research trends

2.1 Introduction

It is stated that agricultural water management is diverse and has strong links to other sectors and to the broader economy and it is at the crossroads between four areas of public policy for sustainable growth: water resource management, agriculture, rural development, and the environment. And in our context we focus on the intersection of environment for sustainable development, in spite of current time frequent happening of high and low rainfall less work on soil conservation practice and deforestation are causes of changing of climate and land degradation make the need for resilient agricultural water management and so efforts towards resilient agricultural water management is must and so i focus on different literatures that focus on management of agricultural water for this changes to have good understanding of the challenges and the need for new approach to optimize agricultural water demand sustainably.

In south omo gibe sub basin there are no institutions that try to optimize the use of water for agriculture and to improve the competitiveness of this sector to achieve sustainable development. And so it is important to review agricultural water management research trends in different places in different countries in response to climate change and land transformation and irrigated areas experience in different levels of advisory in order to find best options to find adaptation strategy that optimize the use of water for agriculture for this paper case study south omo gibe basin.

In the sequent sub topics we review different literature of agricultural water management for the change of climate and land transformation with the impacts independently and together and then I review previous study of modeling agricultural water management which incorporates adaption strategies for the changes.

2.2 Agricultural water management problem in the sub basin

Now a time In south Omo Gibe basin a frequent happening of high and low rainfall, less work on soil conservation practice and deforestation are observed as causes of changing of climate and land degradation that make the need for improved and resilient agricultural water management and so efforts towards improved and resilient agricultural water management is must.

The agricultural sector is the main water consumer in the region (more than 90%), which plays an important economic and social role. The transformation of large rain fed areas into irrigated lands during the last 10 years has limited the emigration of rural populations to cities

or other industrialized regions of area. The water used for this transformation is mainly surface water.

Tension between agricultural production and protection of natural resources is growing. Farmers and investor face increasing difficulty in fulfilling their trusteeship role as many countries approach the limits of water and land resources due to poor participatory integrated watershed management and poor natural resource conservation practices for agro forestry development. Much irrigated land suffers from drainage problem. The third-party environmental costs and risks of irrigated agriculture have grown: loss of environmental water flows; groundwater over exploitation; pollution; destruction of natural habitats and livelihoods through drainage of wetlands.

In the sub basin Governments have led the expansion of large-scale irrigation projects but performance has been suboptimal. With strong investment and management input from government, large-scale irrigation has contributed to rapid increases in food production, the major public policy goal. However, the supply-led approaches and large-scale irrigation infrastructure that were to fuel growth have resulted in bureaucratic institutions that lack the structure and incentives for efficient management, and in inflexible water delivery systems that does not capable of responding to farmer needs.

In lower omo gibe basin large scale irrigation project is dominated the area agricultural irrigation activity and in these paper one of the large scale irrigation project, kuraz sugar development irrigation project is taken as a case study because the project design report incorporate the development work of the communities on their crop and livestock development and the challenges of these project is good to represent the sub basin challenge of agricultural irrigation development and so the design report is taken as a bench mark for the assessment of challenges of agricultural water management in the sub basin.

As said in the previous chapters there are many problems in the sub basin and Kuraz sugar development project area in particular that concern the methods adopted to manage the distribution of nutrients and water between plants. The soil of the lower Omo Gibe Basin is isotropic, homogeneous and very porous also the chemical properties of the soil should be managed for productive agriculture output. WWDSE in its study design of kuraz irrigation project recommends the need for further research on this area like stabilization on the cane cycle, study on fertilizer type rates and application method, management of irrigation application, determination of appropriate dry off period for plant cane ratoon on different soil type, management of sodic and saline soils, drainage improvement and erosion control measure

Many questions we must ask are: which nutrient to use to which type of plant in this kind of soil? How it is distributed and what is the quantity really absorbed by the roots of plants? If the amount of water used to irrigate represents really what the plants need? How the water infiltrates in this type of soil? How to quantify the water lost and how to distribute it between

plants with an efficient manner for this special architecture? If the disposition of the existing species is the best for an efficient use of solar radiation in order to minimize evapotranspiration and maximize the photosynthetic process?

The south omo Sub basin is characterized by a steep elevation gradient in northern plains which is dominated by intensive cultivation of arable crops while southern parts are mostly used for livestock and fodder productions. The sub basin is also characterized by relatively low precipitation levels, and irrigation is a common management strategy for certain crops. Water resources for irrigation are mainly withdrawn from surface water bodies, and water scarcity in rivers is regularly a serious issue in this catchment according to the design report of WWDSE.

Government began intensified reclamation of farm land in the sub basin and the expansion of arable land was accompanied by mechanization agriculture. The current irrigation systems in sub basin are causing problems of rising or declining groundwater levels, waterlogging and salinization (Dereje 2012). Typical problems in kuraz irrigation project for example are canal water scarcity, poor groundwater quality, rising or declining groundwater levels, water logging, secondary salinization and limited crop production. These water management issues are very complex, and must be addressed by better planning and management.

Water availability constraints in the sub basin agriculture land are higher than those found in other places of the countries. Therefore, production of crops is usually lower than that found because commonly used water requirement estimations for irrigation scheduling are not adequate under stressed conditions, being thought for complete water completion requirements. New trends are emerging, linked to the dramatically growing water scarcity problem. These trends are promoting deficit irrigation approaches that need new approaches for evaluating water needs under stressed conditions

Basically the sub basin has limited water resources, which does not make well-organized utilization of amount of available water. Farmers and investor are lack of knowledge of actual irrigation water needs and irrigation scheduling techniques are still mainly based on the amount of maximum water available for a farmer. Therefore present irrigation methods in the area show a tendency to over irrigate, while the reverse should be accomplished. Currently very little is known regarding water utilization efficiency in context of south omo gibe basin. However, due to less efficiency water allocation the production from per unit land area is low. Further investigation is needed to address the impact of irrigation water allocation, distribution and scheduling on different crops productivity.

Before we put an option for efficient agricultural water management let see the extent of the impact of climate change and land transformation with their driving forces in the sub basin.

2.3 Climate and Land use change impact Assessment on crop requirement of Agriculture Land in the study area

Assessing the effect climate change and soil change for with quantifying the effect of climate change and solute movement on crop yield enable us to know how much is the effect and how much attention should take to natural ecosystem reservation and conservation. And the aim of these sub topic focuses on technical approach to meet the sub basin irrigated development challenge which gives one set of integrated output through adapting, learning and planning tool from agro ecological perspective using innovation system. In this section the observed changes of temperature and land degradation are assessed and possible with possible driving factors based on the data from WWDSE report and different researches done on the sub basin like findings of the IPCC Report.

Due to the large water demand, agriculture will suffer most when the water resources are not locally available anymore. The effect of climate change how it affects the crop yields should be quantified and measures taken should be known on increasing soil temperature, and so referring different researches is helpful to know the effect of climate change and land transformation in the sub basin to understand the method of quantifying their effect on crop yield as it is stated in literature review.

Rise in the mean temperature above a threshold level will cause a reduction in agricultural yields. A change in the minimum temperature is more crucial than a change in the maximum temperature. Livestock are also affected differently by drought. Livestock production took large scale in the study area. Feed resources were mainly from agricultural by-products and nature grass. Nature grass was the main feed for cattle production. High temperature and lacking of water reduced grass development capacity or even made nature grass drier or died. Therefore, cattle and are the most affected by drought. According to research done on climate change, planting time germination is influenced by external facts of soil moisture, soil temperature and aeration of the external factors

During high rainfall in the agricultural land the water table is to raise to the surface and cause salt accumulation in the top soil and hampering plant growth.so it is important to closely monitor changes in ground water table to assures a well maintained and controlled drainage of the irrigated area particularly in low lying parts for closely control and maintain high efficiency irrigation.

Now time leaching and increasing temperature related with drought affects soil evaporation in the sub basin plant transpiration, Indications that climate change is already taking place have been repeatedly reported in recent studies in the sub basin, and an increase in surface air temperature of 0.9 °C in annual mean temperature is recorded over the entire sub basin has been observed during the period 2010-2015, that have a potential to reduce crop yields in the area so that the actual transpiration will differ from potential transpiration of the result of crop oriented model.

High evapotranspiration rates and insufficient irrigation and drainage management lead to the accumulation of pollutants and salts on the agricultural fields and soil salinization will occur on the middle sections of the downward slope from the mountains to the semi-arid basin. According to the soil property of the soil the area is covered by poorly drained sodic soil and this will aggravate drainage problem.

Water logging is a common problem associated with surface irrigation. It results primarily from inadequate drainage and over-irrigation and to a lesser extent from seepage from canals and drainage ditches. Other causes may include low irrigation efficiency, poor water distribution systems and poor main system management. Due to relatively shallow groundwater depth and nature of the soils in parts of the Project area, a highly possible impact is projected. These causes rising groundwater tables in certain areas and secondary salinization when the capillary forces transports water to the surface where it is evaporated and leaves the solid substances as mostly observed in different places in the countries agriculture land. In the area there is observed poor salinity management and poor drainage management.

Soil erosion is one of the major problems of the study area as siltation in the canal reduces the head of water flow. According to the data on soil nutrient level organic carbon content, total nitrogen level, soil acidity or alkalinity and water quality in the proposed project area will be affected by the introduction of pollutant that may be discharged from upstream area flood and irrigation drainage.

Results of different researches in Ethiopia including south omo gibe basin, indicate a trend for median productivity to decrease by 2– 3%, for median erosion to increase by 25–30% due to shorter crop growth cycles and increased rainfall intensity in fall/winter, and for median nutrient leaching to increase by 43 – 52% as a consequence of higher mineralization rates in a warmer and sufficiently wet climate. A trade-off exists among agricultural productivity and environmental impacts, and results show that this trade-off aggravates with climate change. Without changes in agricultural land management (status-quo scenario), mean regional productivity of crops in the agriculture land is expected to decrease by 0–10% in the future, in parallel with an increase in water needs by 20–50%. In contrast to those moderate changes in productivity, impacts of climate change on erosion and nutrient leaching are expected to be largely negative (increase by 30–45% for leaching and 25–35% for erosion).

Different studies in the sub basin shows also the onsite financial cost due to nitrogen and phosphorus lost associated with nutrient depletion was estimated to be USD 200/hectare. These revealed that economic impact of soil erosion which is variable based on the characteristics of land resource and management practices are immense and deserves due attention so that information on suspended sediment and plant nutrient losses in runoff with their economic cost can provide crucial evidence to inform the land user and policy makers to take action in management of land resource using econometric modeling of crops. However,

erosion which are important data to be model with Agro hydrological model doesn't not give emphasize by the client of irrigation projects to know how much yield is to be reduced due to climate change and its follower land degradation.

When we see technological improvement in the sub basin; lack of technological improvement that measure and control silts in the canal which affects infiltration of the surface soil and decreases the head of water in the canal; lack of measuring instruments like lysimeters which measure soil moisture and soil temperature in the soil for better irrigation management; lack of technological mechanism to measure solute transport and nutrient management like salt content measuring instruments in the agricultural land in the sub basin, as it is important for improved mechanism of water and solute movement during raining, are challenges for improved irrigation water using in the sub basin .

The other challenge in the sub basin is that there is no controlled drainage system of the irrigated area like tube well technology so that we can't assure a well maintained monitoring of ground water table which causes salt accumulation. Beside, inadequacy of good storage reliability mechanism as we can observe kuraz irrigation project cofferdam is filled by silts due to no silt trap mechanism like small dams building to capture runoff from upper watershed after heavy rains that reduce erosion which contribute for poor agricultural water management in the study area. Sediment concentration and nutrient concentration data we get in the sub basin also shows there is poor land management practices and ineffective and in efficient river water management practices are used in the sub basin.

When we see the agriculture practice of the area there is no mitigation strategy for climate change and Land transformation using institution like irrigation advisory system with field assessment and policy frame work for adaptation mechanism, so that soil moisture and ground water level data are not available so that it cannot be quantified how much effect it has on crop yield. The current available crop wat model is unable to quantify the impacts of climate change and land degradation has on agricultural water management in the sub basin. Sugar corporation that hold large agricultural land in the sub basin also shows no responsive mechanism for the change of climate that affect soil temperature and solute movement with siltation due to land degradation on upstream of the agriculture land area,through improved option and integrated approach within river basin scale to cope up these challenges.

Consequently, less attention is given on identifying the impact of environment on the yield of sugar cane and different researches shows that the intervention and different institutional arrangements to mitigate the adverse effect of climate change and land degradation is necessary to reduce these challenges.

According to climate change assessments, less precipitations and higher temperatures can be expected in the sub basin as we have seen above and plants are subject to variety of environmental stresses, including inadequate temperatures, physic-chemical conditions of unfavorable soil and various diseases and pests. Despite their location corresponds to the

temperate climate area, solar radiation rates in south part of the country is relatively high. This radiation conditions could lead to higher crop transpiration rates.

However, water is a limiting factor affecting plant growth, development and yield, especially in arid and semi-arid regions, where plants are often exposed to water shortages, also known as water stress. For sugar-cane which is the dominant crop in the study area, high temperature provides increasing evapotranspiration in plants well supplied with water, but in plants under water deficit causes reduction in leaf area, growth of tillers and stimulates senescence of leaves. According to soil survey and land evaluation reports, soils identified and mapped in the command area of Kuraz project have some limitations/constraints as listed below. Low soil fertility status (low organic carbon and total nitrogen contents in most of the soil mapping units, low levels of available P partially in the soil mapping units and low exchangeable K in some of the mapping units); drainage deficiency; slow permeability; heavy texture/structure; limited soil effective depths due to the presence of bed rocks and hard clay pan layers; soil alkalinity/sodicity; the existence of slightly to moderately saline soils in some soil mapping units. The probable occurrence of seasonal flood risks in some of the soil mapping units which are occurred mainly in the stratified alluvial/flood plains located along the Omo river banks and other tributary streams require the application of appropriate flood protection measures.

Effects of drought due to climate change on sugarcane growth and development depend on plant growth stage, the degree of water deficit stress, and duration of the stress and for sugar cane, the early development is the most sensitive period to water deficit. According to different studies culture requires between 1,500 and 2,500 mm per season and irrigation management should be done according to the phenological stages of each variety.

According to the design report of WWDSE regarding to the exchangeable sodium percentage (ESP) levels of the soils, some of the mapping units with the pH values >8.5 have exchangeable sodium percentage (ESP) varying between 15 % and 59 % in their sub soils reflecting the existence of sodic hazards at varying levels. However, the soils with the ESP values as high as 15 to 30 % can be managed by applying appropriate soil management/amendment practices such as gypsum application and leaching of the soils after replacing Na by Ca at the exchange complex by gypsum in some cases the presence of slight to moderate salinity in their sub-soils with E_{ce} of soils in saturated paste extract ranging from 6.52 - 13.5 mS/cm requiring the application of appropriate soil management practices such as leaching of the soils.

In order to improve water management and its productivity, we need to reveal the cause-effect relationships between hydrological variables such as evaporation, transpiration, percolation or capillary rise, and biophysical variables such as dry matter and grain yields under different eco hydrological conditions

This research project in the south omo gibe sub basin has mainly been aimed at developing a methodological approach for the assessment of the changes in climate and land transformation

systems for future megacities. Some of the inherent constraints and challenges are discussed, along with possible measures to overcome them, after evaluating and discussing the models' function and its results, a final focus is laid on its transferability and the possibilities of improvement.

This study intends to evaluate the recent and future situation by combining a Agro hydrological model as we will see below for the simulation of the water supply based on scenarios of climate and land use change. Since most of the data input used for modelling in the sub basin was derived without extensive field research and with freely available data mostly from WWDSE design report, due to data and computing restrictions, not all processes of the hydrological system are accounted for. This research focused on the most important ones and the ones that could be modelled with the available data. When different output, scale or time steps are desired, the Agro hydrological model described and used here has to be adapted according to requirements. Several nearby possibilities to improve and extend the model are explained within this chapter.

2.4 Review of agricultural water management simulation model

2.4.1 Simple Crop Water-Use Simulation Models Crop wat

Crop wat for Windows is a program that uses the FAO (1992) Penman-Monteith method for calculating reference crop evapotranspiration. These estimates are used in crop water requirements and irrigation scheduling calculations.

The program uses the same Penman-Monteith methodology as used in Crop wat versions 5.7 and 7.0 and uses the same data such as the CLIMWAT climate and rainfall data files.

In Crop wat the monthly ETo is converted into daily values. Crop wat for Windows accepts monthly average climate/ETo data only. For crop water requirements (CWR) and irrigation scheduling purposes, the monthly ETo has to be distributed into equivalent daily values. This is maybe sometimes unreasonable, as the rainfall is not uniformly distributed throughout the month. But it may give the more simple way to calculate evapotranspiration and it require less detailed rainfall data. As meteorology data for Crop wat are based on monthly basic that can accept some data missing in daily records which is the case in SWAP.

2.4.2 Soil Water Atmosphere Plant SWAP model

Transport of water in the unsaturated zone primarily vertical and can be simulated with one dimensional direction (van Dam et al., 1997). SWAP (Soil-Water-Atmosphere-Plant) is a model to simulate transport of water in the unsaturated zone in interaction with vegetation development. This is an integrated model has been implemented in a computer code to calculate water flow, solute transport and crop growth. This model is proven to be powerful in

predicting the interaction between soil, water, atmosphere and plants. This software has been used by several researchers (e.g. Kroes and Supit 2011, van Walsum 2011 in the Netherlands, Vazifedoust (2007) in Iran, and Yano (2007) in Turkey) to predict the impact of drought and future climate on crop yield and water demand. Therefore, this model can be applied here to analyze the impact of drought and nutrient leaching now and in the future on water demand and crop yield in the area kuraz irrigation project.

All these capabilities can be used at the field level to integrate a general farm water-management, trying to help farmers and institution to control water more efficiently and to improve the environmental and economic performance of irrigation systems. SWAP is specifically oriented to water management, but comprises the WOFOST also, which make SWAP able to simulate crop-growth as well. Nevertheless, SWAP simulation outputs should be compared to other similar modelling approach.

3 Methodology

3.1 Research Methodology Frame work

An essential feature of agriculture is the ability to adapt to natural variability to ensure long-term sustainability of food production. To this end, a large number of existing farm-level management practices are already available as a basis for devising climate change response strategies needed in coming decades. These include growing new varieties and species that are more adapted to altered thermal and hydrological conditions; rescheduling of farm management practices such as irrigation and nutrient application to better match altered phenological cycles; implementation of technologies that conserve water and soil, etc.

As pointed out earlier negative climate variability impact could be reduced by following adaptation option that focuses with best irrigation management strategy that fit soil and water management. A need for model which optimize both adaptation techniques for climate change and land use change scenario explore water management option by crop growth and soil water balance modeling.

Therefore, the strategies for adaption to the changes of climate and land transformation are based on the assumption that the agricultural water consumption will decrease. Which means Agriculture will have to reduce either its relative water consumption per output by improving the usage efficiency or absolute water demand by reducing agricultural production .To produce more agricultural output per area and water used (crop yield and crop water productivity) means to achieve more crop per drop which has also been presented by the Food Agricultural Organization as a strategy to resolve the countries water problems.

3.1.1 The need for change of irrigation practice with modelling approach

As a measure how to react to the effects of climate change on the agricultural water demand side, possible strategies for the intensification of agriculture have to be considered. To achieve an intensification of crop cultivation, irrigation, soil, and crop management were considered. The improvement of irrigation techniques and soil and water management aims at increasing the yield per water unit used and reducing evapotranspiration by plants and soil. It can be measured by increased crop water productivity (CWP) and inversely by reduced ‘virtual water content’ of the crop (VWC). Adding more irrigation water normally leads to an increase of yield, but not to an effect on the ratio of crop yield to water consumption with better irrigation management

The option for adaptation can be defined at three levels these are: at farm level, irrigation system level and river basin level, so this implies a need for better adapting tools like agro hydrological models in the sub basin for improved agricultural water management.

In order to manage the increase of water infiltration, erosion control and soil moisture maintenance and assessing the effect of agriculture yield due to lowering of ground water table should be studied. Optimization techniques permit identifying optimal value for decision variable land use type and soil and water management practices to achieve management goal and using model is important.

3.1.2 Modelling Approach to use SWAP model comparing with CROPWAT model

The aim of this research work is to evaluate the performance of two computer-based agro-hydrological models (SWAP and CROPWAT) in simulating soil water balance components of a sugarcane cropped field under irrigation condition.

However before comparison of the performance of the two models it is necessary to see the line and framework of methodological approaches to select a model for comparison in our case study area irrigation project design work modeling approach.

In general the concepts of this study comprehend a case Study kuraz irrigation system in south omo gibe basin, which is devoted for improving the irrigation water allocation and use for sugarcane crop through adapting the system with climate change and land degradation. Since the need for improving agricultural water management in general and irrigation water management in particular is necessary in recent time in order to mitigate climate and land use change so that we can get greater yield for economic growth.

For this reason the solution ways for relevant problems have been addressed, through the assigned scopes which are the application of CROPWAT model to first estimate crop water requirement (CWR) according to the design work for of kuraz irrigation project for this paper time period interval with Agro hydrological model after assessing the constraints and advantage of the models with respect to the consideration of the effect of climate change and land transformation. Consequently in this subtopic we will see the criteria for selection of agro hydrological model SWAP before we go to comparison.

There are three methodological approaches for assessing climate change and land transformation impacts and adaptation strategies in agricultural water management (Kates, 1985 cited in Carter et al., 1994).

First, the simplest methodology is called impact approach. It is considered simple because it follows a straightforward “cause and effect” pathway or it can be thought of as an “If - Then - What” approach. We can understand that if the climate change or land transformation happens, then what would be its impacts?

The second approach is interaction approach. This

approach recognizes that climate factor or land use factor is only one of a set of factors that influence or is influenced by the exposure unit. This means that exposure unit is not only affected by climate factors but also by land transformation. Interaction approach can be thought of as a “What-Then-If”. We can understand what issues in a system are sensitive to climate change and land transformation and then what fields will be impacted if climate change happens? This approach is similar with irrigation level adaptation plan that consider best option for soil and water benefit management of agricultural land to bring greater yield.

The third approach the integrated approach is the most comprehensive regarding the interactions between climate factors and land transformation. This approach seeks interaction within sectors, between sectors and feedbacks. It also refers to adaptation strategies to moderate negative impacts.

Therefore considering the above methodological approach let us see which model will fit best for our case study area. Decision support systems models are widely used to examine options for adaptation by stakeholders and policy makers as they have the ability to explore large sets of agricultural practices. So we will see below improved agricultural water management model with soil and water benefit in field scale through integrated sub basin approach that can be used to optimize irrigation water management for improved yield of crops. So first let see top soil which are important input for crop growth model which play large role for climate change and land degradation impacts in both intersection and integrated approach.

In top soils occur numerous physical, chemical and biological processes, with all kind of complexity and interactions. Although analytical equations are elegant, provide insight and are rapidly transferable, they are in general insufficient for field conditions. The interaction between highly non-linear processes under irregularly changing boundary conditions as occurring in the field cannot be solved by analytical equations. Numerical solutions of the governing relationships are much better equipped to solve these processes at the prevailing boundary conditions. Our increased knowledge of numerical stability the exponential growth of computer speed and capacity, the accessibility of input data and availability of support through the Internet, and the increasing interface user’s friendliness, have enhanced the development and application of numerical models. One of these agro hydrological models is the Soil-Water-Atmosphere-Plant (SWAP) model.

Since Irrigation water management relies on accurate knowledge of plant water consumption, water flows and soil moisture dynamics throughout the growing season. The decision-supporting tools should therefore capture well the temporal and spatial variability of rainfall, soils, and crops. This cannot be reconstructed fully from field measurements or remote sensing, so dynamic simulation models are deemed necessary to describe soil physical processes, the surface water balance and crop growth in order to provide this information to the stakeholder and finally derive water productivity estimates.

The role of simulation models in understanding the processes in the soil-plant-atmosphere system has increased significantly in recent years. This is attributed to increased computing capabilities available today. Mathematical models, be it physically or empirically based, have the promising potential to explore solutions to water management problems. Evaluation of water management scenarios can be easily done, thus facilitating better recommendations for improved water use. Thus in large scale irrigated agriculture there is also potential benefit from improvement in rainwater and irrigation management and upstream through reduction in land degradation and associated soil erosion which when transported to downstream reduces the efficiency of irrigation scheme and enhancement of best practices in relation to selected area.

3.2 Methodology for overall objective

3.2.1 Comparison methodology

Comparing model results with field observations or inter comparing models of different nature will provide information on the performance of the models and will reveal strong and weak points. This is essential in selecting appropriate models for practical applications in water resources analyses. A comparison of a physically based soil-plant-atmosphere model to a simpler one will give information on how the model fares in its performance compared with the other. If the simpler model can sufficiently simulate the processes, then this could be a good alternative to data-intensive complex simulation models. This makes sense from an economic point of view, because this will minimize the need for comprehensive data in the simulation..

What is the advantage of Agro-hydrological model?

Very often, attention is only paid to water applied by irrigation. However, it seems obvious that, with the increasing competition for water, considering only irrigation water is not adequate and an approach encompassing the total water balance is necessary. However, most experiments are still conducted using the classical approach of investigating the effects of different amounts of irrigation applications or different irrigation methods on crop yields. These studies are mainly focusing on obtaining the highest yield per unit of irrigation water and ignore some important issues.

They take into account only water applied by irrigation, while ignoring water consumed by the plant from other sources, such as capillary rise from the groundwater, rainfall, and reduction in soil-water storage. For determining savings in agricultural water use, three processes should be considered: the distinction between crop transpiration and soil evaporation, groundwater recharge vs. capillary rise, and changes in long-term soil-water

storage. Unfortunately, only the last term can be easily obtained from soil-moisture measurements in the field.

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What are constraints of Crop-Oriented Models Regarding the Simulation of Soil Water movement and Crop Water-Use?

Actually, water moves not only down within the soil, but also lateral and even upward, depending on the potential gradients (Kutilek and Nielsen, 1994). Transport phenomena, as water movement into the soil, are driven by potential gradients that depend on gravity, water extraction by roots and water that enters or leaves the profile from top or bottom, causing different soil water suctions in the different layers.

The cascade approach could be appropriate on sandy soils or if the objective is to calculate the amount of water available to the crop over longer periods of time. However, this approach could fail in soils with significant clay and silt content and if the objective is to calculate daily soil-water profiles, as needed in irrigation assessments.

Crop Wat is best used for general design, planning and operation of irrigation systems and to provide a rapid assessment of crop performance under water-limiting conditions; or to identify water allocation priorities at a regional or national level as environmental conditions are homogenized over space and time highlighted other shortfalls of Crop Wat, including the inability to carry soil moisture over calendar years due to the fact that simulations are programmed to run for discrete, individual years despite the facility Eto use daily values of rainfall and ET .

3.2.2 Irrigation Evaluation of simulation models with soil plant water interaction

Irrigation interval is mainly dependent on evapotranspiration and water holding capacity of soil or soil type. If we take sugar cane irrigation land soil of the state is categorized into four irrigation classes based on moisture holding capacity which ranges from 120 mm to 143 mm per one meter soil depth Based on depletion level of the soil, which is 70 % of available soil moisture, water will be given at different interval for each soil type and varied from 13 up to 30 days.

In most applications, we are not only interested in the systems behavior in a particular or 'average' meteorological year, but also in its behavior during extreme weather periods. A clear understanding of all the components of the water balance is essential to analyze possible measures of water savings in irrigated agriculture. However, most components of the water balance are not easily measurable either in terms of the required time interval or the complexity of the processes. For an irrigated area in different countries, the physically based one-dimensional agro-hydrological model SWAP for water transport and crop growth was applied in a distributed manner to reveal all the terms of the water balance. A combination of point data and distributed areal data was used as input for the model.

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The distinction between soil evaporation, which is considered as a loss by agriculturalists, and crop transpiration is difficult to measure. Only specific measurement techniques, such as micro-lysimeters for soil evaporation or sap-flow measurements and porometers for crop transpiration are able to make a distinction between the two water fluxes towards the atmosphere. Water fluxes from or towards the groundwater are only obtainable by continuous

soil-water measurements using automatic methods, which are very expensive and rarely applied in production agriculture. The use of simulation models is an attractive alternative to reveal processes that are difficult to measure. The models applied at irrigation system scale are mostly oriented to hydraulics although they sometimes include a simple soil-water balance module. These models are very suitable as operational tools for managing irrigation schemes, but are not able to describe the hydrological processes in great detail. On the other hand, many physically based models exist which can simulate all the components of the water balance in great detail, including crop growth, irrigation, fertilizer applications and solute transport. These models are usually considered as point-scale models and are not commonly used for larger areas.

Soil moisture reflects the balance of precipitation; runoff, and. Infiltration, surface run-off and evapotranspiration have been identified as the key factors determining soil moisture content at fine scales. Evapotranspiration (ET) is a large term in the water balance equation in arid and semi-arid areas, including evaporation from soil and transpiration from vegetation, which are processes that affect crop development.

So linking water management with the agricultural development through integrated approach can be best expressed using Agro hydrology model that works with both scenarios. We can get data from metrological station or satellite data also sediment concentration from SWAT to check for the available nutrient and ground water data from MODFLOW that can be input for SWAP model which is the common agro hydrology model. These interventions are designed to eventually raise the productivity of all natural resources in a watershed so that soil becomes more productive for agriculture.

Very often availability of model input data (especially soil input data) is a serious limitation for applications of complex crop water balance models as to be used for irrigation scheduling. This is especially a problem in poor agricultural regions, where input data generation might be a serious cost factor. The limitation on input data quality can lead to the situation that simple models or methods like Crop wat may not perform better than the complex models. The limitation on input data quality can lead to the situation that simple models or methods may not perform better than the complex models. That is why for experimental sites the performance of a simple approach will be tested with alternative option. The test will result in defining limitations and potentials of both simple and complex approaches.

Agriculture, being considered the major user of water, is a potential avenue to study water use efficiency. A strategic point to start with is to answer the question of how much water is really needed to grow crops. But even this question is difficult to answer because of the

interrelationship of factors in the soil-plant- atmosphere system. It is more difficult if the issue expands to how crops are using the applied water in the soil.

3.3 Estimation methodology for crop water requirement and irrigation requirement

3.3.1 Crop water requirement and irrigation schedule evaluation

To analyze water flow in a SWAP model system, one need to know the three boundaries mentioned earlier (i.e. top, bottom and lateral boundaries). For the top boundary (i.e. interaction between soil and atmosphere), the amount (available data or prediction) of rainfall and irrigation. Based on the meteorological data (i.e. rain, temperature, humidity, radiation, and wind speed) and crop model, the amount of water intercepted by the crop leaves and the amount of water extracted by the crop roots can be modeled. Further, based on the properties of the soil and meteorological data, the amount of water infiltration into the soil and surface run-off can be model. For the lateral boundary (i.e. interaction between soil and surface water level), the depth of surface water level and the depth of the ditches should be given. When the ground water level is well below the surface water and depth of the ditches, lateral infiltration will occur and if otherwise, drainage will occur. The rate of infiltration or drainage is very much influenced by the infiltration and drainage resistance of the soil being modeled. For the bottom boundary (i.e. upper part of saturated zone), depending on the spatial distribution of water pressure head, water recharge (water flow from unsaturated zone to saturated zone) or discharge (water flow from saturated zone to unsaturated zone) could occur.

Depending on the given boundary conditions, SWAP model will calculate soil water flow due to the spatial differences of soil water potential. Soil consists of different organic matters and

$$q = k(h) \frac{d(h+z)}{dz} \quad 4.1$$

can be modeled as porous media with permeability properties as described by Darcy's law:

where q [cm/day] is the soil water flux density (positive upward), K is hydraulic conductivity of the soil [cm/day], h is soil water pressure head [cm] and z is the vertical coordinate [cm] taken positively upward.

When water content changes with time under transient conditions, conservation of matter is formulated by the continuity equation for soil water:

$$\frac{\partial \theta}{\partial t} = -\frac{\partial q}{\partial z} - S(h) \quad 4.2$$

where q is volumetric water content ($\text{cm}^3 \text{ cm}^{-3}$), t is time (d) and S is soil water extraction rate by plant roots and drain discharge ($\text{cm}^3 \text{ cm}^{-3} \text{ d}^{-1}$).

By combining equation (4.1) and (4.2) one could derive the partial differential equation that describes the soil-water-atmosphere interactions in unsaturated zone which is the well-known

Richards equation

$$\frac{\partial \theta}{\partial t} = C(h) \frac{\partial h}{\partial t} = \partial \left[\frac{K(h)(\partial h / \partial z + 1)}{\partial t} \right] - S(h) \quad 4.3$$

Where C is the water capacity (S_0/dh) (cm^{-1}), h soil water pressure head (cm), K is hydraulic conductivity (cm d^{-1}), S root water extraction rate ($\text{cm}^3 \text{ cm}^{-3} \text{ s}^{-1}$) and z soil depth (cm).

Hydraulic conductivity is an intrinsic representative property of the soil being studied. This soil property depends very much on the type and structure of the soil. In addition, atmospheric temperature and thus soil temperature will also have an impact on this hydraulic property of soil, which all are included the SWAP model. Root water extraction rate depends on the crop model and the atmospheric conditions, while the water pressure head depends on the initial condition and further calculated spatial distribution of water pressure head depending on all the boundary conditions and soil properties.

Richard's equation (equation (4.3)) is solved by SWAP numerically given the initial conditions, the boundary conditions and the relations between volumetric water content (q), soil water pressure head and hydraulic conductivity of the soil being studied. The reader is referred to SWAP manual for further detail on the numerical methods implemented in SWAP program.

In SWAP model the depth of the surface water level, the depth of the bottom of the channel is modeled and is influencing the ground water level. In this study no drainage system was applied since the limitation of data. The drainage flux relation conducted Hooghoudt or Ernest equation:

$$q_{drain} = \frac{(\varphi_{gwl} \text{ OR } \varphi_{avg}) - \varphi_{drain}}{\gamma_{drain}} \quad 4.4$$

Bottom boundary could be defined as the transition between un-saturated and saturated zone in vertical direction. Between the aquifer and the ground water level is a semi confining layer with a certain thickness and a certain resistance. Bottom flux (q_{bot}) can be calculated as

$$q_{bot} = \frac{\phi_{aquif} - \phi_{ave}}{C_{conf}} \quad 4.5$$

where f_{aquif} is the hydraulic head of the drain (cm) and f_{ave} is the average ground water level (cm) and C_{conf} is the semi confining layer resistance.

3.3.2 Estimation methodology for comparison of current and actual field condition

For understating the current and actual field situation it's required to know how much water is given for difference crops in each month for the practiced crops in the study area, with the existing irrigations efficiency, secondly it's necessary to explore monthly canal available water for the crops in the study area. CROPWAT is taken in account for simulating the net irrigation requirement of each crop in the study area, and canal flow is estimated. The result of this scenario helps to quantify irrigation water requirement.

To find out the crop water requirements (CWR) and irrigation water requirements (IWR) through CROPWAT model the following steps and information is required.

- Decade or monthly climate data that is minimum and maximum air temperature, relative humidity, sunshine duration and wind speed is required by the model.
- Reference crop evapotranspiration (ET_o) equation based on Penman-Monteith method

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad 4.6$$

Whereas,

ET	= reference evapotranspiration [mm day-1]
Rn	= net radiation at the crop surface [MJ m-2 day-1]
G	= soil heat flux density [MJ m-2 day-1],
T	= mean daily air temperature at 2 m height [°C]
u ₂	= wind speed at 2 m height [m s-1]
E _s	= saturation vapour pressure [kPa]
E _a	= actual vapour pressure [kPa]
e _s -e _a	= saturation vapour pressure deficit [kPa]
A	= slope vapour pressure curve [kPa °C-1]
Y	= psychrometric constant [kPa °C-1]

- Rainfall data (daily/decade/monthly) is required to calculate effective rainfall, for this study USDA Soil Conservation Service method has been chosen for the calculating of effective rainfall; following criteria have to be followed.

$$ER = \text{Total R}1(125-0.2 \text{ TR}) / 125 \dots\dots\dots(\text{Eq.4.7})$$

A cropping pattern consisting of the planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction) and the area planted (0-100% of the total area) and also a set of typical crop coefficient data files are provided in the program.

CWR and IWR computes due to the following formula, on the account of CROPWAT model.

$$CWR = ETo * Kc \quad (\text{Eq.4.8})$$

$$IWR = (ETo * Kc) - ER \quad (\text{Eq.4.9})$$

As described earlier, crops leaves intercept water from rain and irrigation. In SWAP, the amount of intercepted precipitation is calculated based on a formula proposed by Von Hoyningen-Hune (1883) and Branden (1985):

$$P_i = a \cdot LAI \left(1 - \frac{1}{1 + \frac{b \cdot P_{gross}}{a \cdot LAI}} \right) \quad 4.10$$

LAI where Pi is intercepted precipitation (cm/day), LAI is leaf area index, P_{gross} is gross precipitation (cm/day), a is an empirical coefficient (cm/day) and b represents the soil cover fraction. Equation (4.6) shows that the amount of intercepted precipitation will asymptotically reaches the saturation amount (i.e. a-LAI) for increasing amounts of precipitation.

It is generally accepted that the daily water fluxes passing through a canopy are large compared to the amounts of water stored in the canopy itself. Therefore, it can be assumed that root water extraction in the soil is equal to plant transpiration. On the other hand, due to meteorological conditions, water from the soil or ponding on the soil surface can evaporate. The total amount of transpiration (from plant) and evaporation (from soil surface) can be referred to as evapotranspiration. it can be calculated by using Penman- monteith equation.

$$ET_p = \frac{\frac{\Delta_v}{\lambda_w} (R_n - G) + \frac{p_1 \rho_{air} C_{air}}{\lambda_w} \frac{e_{sat} - e_a}{r_{air}}}{\Delta_v + \gamma_{air} \left(1 + \frac{r_{crop}}{r_{air}} \right)} \quad 4.11$$

where ET is the transpiration rate of the canopy (mm/day), Δ_v is the slope of the vapour pressure curve (kPa/°C), λ_w is the latent heat of vaporization (J/kg), R_n is the net radiation flux at the canopy surface (J/(m² day), G is the soil heat flux (J/(m² day), p_1 account for unit conversion (= 86400 s/day), ρ_{air} is the air density (kg/m³), C_{air} is the heat capacity of moist air (J/(kg °C), e_{sat} is the saturation vapor pressure (kPa/°C), e_a is the actual vapor pressure (kPa), γ_{air} is the psychrometric constant (kPa/°C), r_{crop} is the crop resistance (s/m) and r_{air} is the aerodynamic resistance (s/m).

Penman-Monteith equation is recognized as one of the best formula to predict evapotranspiration under different climatic conditions. This equation has become an international standard to calculate potential evapotranspiration for a dry, horizontally-uniform vegetated surface. Penman-Monteith equation is applied in SWAP to calculate potential evapotranspiration.

The maximum potential root water extraction rate could be reduced by the stress due to dry or wet conditions. The maximum possible root water extraction rate could be calculated as follow:

$$S_p(z) = \frac{\int_0^{\ell_{root}(z)} \ell_{root}(z) dz}{\int_{-D_{root}}^0 \ell_{root}(z) dz} T_p \quad 4.12$$

where ℓ_{root} is root layer thickness (cm) and T_p is potential evapotranspiration.

$$E_{max} = K_{1/2} \left(\frac{h_{atm} - h_1 - z_1}{z_1} \right) \quad 4.13$$

Soil water pressure head

The maximum evaporation value that to soil can sustain is calculated using Darcy's law:

Where $K_{i/2}$ is average hydraulic conductivity (cm/d) between the soil surface and the first node, h_{atm} is the soil water pressure head (cm) in equilibrium with the air relative humidity, h_1 is the soil pressure head at the first node, and z_1 is the soil depth (cm) at the first node. The value of E_{max} depends on the thickness of the top soil compartments. SWAP recommends therefore for more accurate simulation, the thickness of the top compartments is maximum 1 cm.

By calculating the potential and actual transpiration one can then calculate the relative crop yield based on a simple model defined in SWAP. For each growing stage k the actual yield $Y_{a,k}$ (kg/ha) relative to the potential yield $Y_{p,k}$ (kg/ha) is calculated in the SWAP model using the

$$1 - \frac{Y_{a,k}}{Y_{p,k}} = K_{y,k} \left(1 - \frac{T_{a,k}}{T_{p,k}} \right) \quad 4.14$$

Following equation:

where $K_{y,k}$ is the yield response factor of growing stage k , and $T_{p,k}$ (cm) and $T_{a,k}$ (cm) are the potential and the actual transpiration respectively, during growing stage k .

4 Data Collection and Analysis

(Modelling experiment a case study of kuraz sugar development project)

4.1 Introduction

As described in chapter 3, SWAP users need to define the boundaries (i.e. top, bottom and lateral boundaries of the soil system being studied), the intrinsic properties of the soil and the crop in order to calculate and simulate desired outcome like ground water level, irrigation, relative crop yield etc.

And cropwat also need climate and soil property data and I have take the parameter of soil and crop characteristic and climate data from the design report of kuraz irrigation project and also the parameters defined in SWAP model and the arguments for the chosen parameters are presented also refereeing other manuals beside the design report. However due to lack of solute and ground water data only water transport through soil is simulated and the effect of rise of temperature and silt increase in the canal is analyzed for better agricultural water management with the available metrological and soil data excluding ground water data for bottom boundary.

As it is pointed earlier the comparison on the performance of the two models is done based on the result of evapotranspiration and crop water requirement of the model output and checked with the yield reduction data of sugarcane in the project area. So for our case 3 years data from 2014-2016 is taken to simulate the evapotranspiration and crop water requirement of the sugarcane plant in kuraz irrigation project area. In order to compare the result of the two models with yield of sugarcane, annual crop water requirement is taken from the result table of the of the model output as it is seen on the annex part and most of the data input for the two models are similar and below we will see the data analysis for the models.

4.2 Meteorological data

Daily meteorological data, i.e. precipitation, solar radiation, air temperature, air humidity and wind speed is needed to calculate the evapotranspiration rate with Penman-Monteith equation described in chapter 4. In addition, the amount of water from precipitation is needed as an input to calculate water interception by the plants, surface water run-off and rain infiltration into the soil.

The closest weather station to Kuraz irrigation project is kako station. It is assumed here that the recorded data in kako station is the same as that in the project area. The meteorological data used in this study is obtained from National meteorological station and kuraz sugar development project irrigation design report

4.3 Irrigation depth interval

Based on Kuraz block sugar development irrigation project the right bank gravity scheme irrigation and drainage system of canal will supply 42 m³/day per hectare and the amount of water supply will be increased to maximum 72m³/day per hectare for dry period. And for left bank gravity scheme irrigation and irrigation system of the canal will supply 32 m³/day per hectare and the amount of water supply will be increased to maximum 62m³/day per hectare for dry period. Totally 74 m³/day per hectare for normal days and 134m³/day per hectare for dries period will supply which means design discharge of kuraz right side block main canal design discharge it is 165 m³/s and 155 m³/s for left side main block canal a total of 290 m³/s. Unfortunately, the real scheduled irrigation applied in the field is not recorded. The irrigation type applied in the field is surface irrigation. For simplicity reason, based on the information and provided by WWDSE, the irrigation water amount is set to be 7.2 mm/day for normal month and 10.7 mm/day for dry month. Dry period is defined here as precipitation deficit, i.e. when the total precipitation is below the potential evapotranspiration. For the entire period of interest, the amount of irrigation per day can be realized by calculating the difference between precipitation and potential evapotranspiration for every month based on the meteorological data and applied the criteria defined above (i.e. 7.2 mm/day for normal month and 10.7 mm/day for dry month. The irrigation is applied during the month of April till October.

The year 2014 is known as dry year and in most of the month, the amount of precipitation is well below the potential evapotranspiration. Therefore, the amount of irrigation for the year 2014 is set in SWAP program as 10.7 mm/day. This criterion was applied to every year of interest.

The period between two irrigation events on a given field is called irrigation interval. Intervals have to be determined prior to every irrigation turn. In this connection it should be mentioned that normal practice to be considered together with general appearance of the cane. Irrigation interval is dependent on the growth stages of the crop and soil type. The relationship between the crop and the soil is expressed in terms of soil moisture depletion level. Studies indicated that during vegetative, and yield formation periods, the depletion level, is about 0.65.

Field capacity [FC] is the amount of water held in the soil after excess of gravitational water had disappeared while wilting point [WP] is the point where the plant starts wilting means that water in the soils cannot be absorbed by the plant any more. The difference between FC and WP indicate the amount of water held in the soil for plant use and called Total Available Water [TAW]. All TAW is not easily available for plants rather some portion of the water will

not be taken. Hence, the concept of Allowable Soil Moisture Depletion Level [ASMD] should be introduced. FC, ASMD and WP depend on soil types.

The following equations can be used as a guideline to estimate depths of water to be applied and irrigation intervals.

Soil Groups	Growth Stages	ASM	Root Depths	Depletion Levels	Average Daily ETc	Irrigation Intervals
		<i>mm/m</i>	<i>M</i>	<i>% TAM</i>	<i>mm/day</i>	<i>Days</i>
Heavy Soils	Initial	220	0.30	35	1.87	10
	Developmental	220	0.40	65	4.48	13
	Mid	220	0.50	65	6.49	11
	Late	220	0.65	65	3.33	28
Light Soils	Initial	180	0.30	35	1.87	10
	Developmental	180	0.40	65	4.48	10
	Mid	180	0.50	65	6.49	9
	Late	180	0.65	65	3.33	23

Table 4.1: Average Irrigation Intervals for Plant and Ratoon Fields from WWDSE

Even though, guidelines are forwarded for irrigation intervals, the figures could be adjusted following moisture contents of the soil. For instance, experiences have shown that young cane on brown and black soils could be irrigated with intervals of 31 and 39 days, respectively.

4.4 Crop Data

4.4.1 Crop Water Requirements and Effective Rainfall

The term “crop water requirement” means the total quantity and the way in which a crop requires water from the time it is sown to the time it is harvested. It is very clear that the water requirement will vary with the crop as well as with the place. In other words different crops will have different water requirement and some crop may have different water requirement for different soil condition; depending upon the climate, type of soil, method of cultivation and useful rainfall etc. Frequency and depth of irrigation is very dependent on the water holding capacity of the soil and the root depth.

$$ET_c = ET_o * K_c$$

Where; ET_c is crop evapo-transpiration (mm/day);

ET_o is reference crop evapo-transpiration (mm/day) and

K_c is crop coefficient.

The effects of weather conditions are captured in the ET_o estimate. Therefore, as ET_o represents a factor of climatic demand, K_c varies mainly with the specific crop characteristics. This allows the transfer of standard values for between locations and climates. This has been the main reason for the worldwide acceptance of the crop coefficient approach and usefulness of K_c factors developed in past studies.

Age	Growth Stages	Canopy Cover	Kc Value	Root Depth
[months]		[%]		Cm
0 – 2	Initial	0 - 25	0.3	30
3 – 3	Developmental	25 - 50	0.5	45
4 – 6	Developmental	50 - 75	0.7	60
7 – 11	Mid	75 - 100	1.20	60
12 – 12	Late	100	0.7	60 – 70
>12	Dry off			

Table 4.2: Crop Coefficient [K_c] Values of 14 Months Age Sugarcane from WWDSE

As described in previous chapters, in the area of kuraz project, sugarcane is the crop planted. To date, unfortunately, there is no crop parameters that can be readily be used as input to build SWAP crop model for sugarcane crop.

With respect to crop growth development, a simple crop development model is chosen because the crop growth input data is not available to simulate a detailed crop model. This model represents a green canopy that intercepts precipitation, transpires, and shades the ground which requires data of leaf area index (LAI), crop height (CH), and rooting depth (RD) as a function of development stage. The DVS is phonological stage of the plant which is expressed as $0 < DVS < 2$. For many annual crops DVS value of 0 means at seedling emergence, goes to 1 at flowering, and 2 at maturity. The most essential phonological change

is the one from vegetative ($0 < DVS < 1$) to reproductive stage ($1 < DVS < 2$). Below are the explanations of these parameters.

Leaf Area Index (LAI)

Leaf Area Index is the ratio of total leaf area surface of the vegetation and the surface area of the land where the vegetation grows. This parameter need to be specified as a function of development stage to divide the potential evapotranspiration over the potential (crop) transpiration and potential (soil) evapotranspiration.

Crop height

As described before, in this model evapotranspiration is calculated using the Penman-Monteith equation. The crop height is one of the important physical parameter to apply this method in calculating evapotranspiration.

Rooting depth

Root depth is one of the factors that determine the amount of soil water available for transpiration. In the simple crop model routine, there are many input parameters to be defined. Following sections describe the input crop parameters in the simple crop model.

According to different reports on sugarcane, the extinction coefficient for diffuse visible light and the extinction coefficient for direct visible light were set to be 0.73.

4.4.2 Function of development stage

Further, FAO also provides the data for LAI as a function of development stage (DVS). According to FAO irrigation and drainage paper no. 56 (Allen et al, 1998), the maximum height of a sugar cane tree is taken 4 meters and the rooting depth is assumed to be 100 cm. Yield response factor is the most difficult factor to estimate. In this thesis, a simple crop yield model is selected since there is no available data could be used to estimate crop yield factor for sugarcane and it is not easy to be measured. For simple model, the SWAP manual suggests to use crop yield factor equal to 1 for the whole growing season which is adopted here.

Water stress response function

Finally, for water stress response function, different parameters are defined based on the data suggested by WWDSE design report. In this study, salinity stress is not taken into account and the water in the area of study is taken as fresh water. This is realized by deactivating the function of water stress in the simulation option.

4.5 Soil

Soil water section is one of the main input file beside other files that have been describe in the previous sections. In the following sections, the input parameters for soil properties are described.

The maximum pond layer thickness (cm) is the threshold of water layer thickness on top of the soil surface before run-off starts. Here the maximum thickness of ponding water layer is set at 0.2 cm.

4.5.1 Soil Evaporation and numerical scheme

Soil evaporation is calculated using Penman-Monteith equation described in chapter 4. In some cases however, calculation of actual soil evaporation using soil hydraulic function could be overestimated. Therefore, SWAP allows users to select empirical functions with different coefficients that need to be defined. Here, SWAP manual recommends users (default) to use the combination of reduction to maximum Darcy flux and maximum black. Default soil evaporation coefficient for black equals to 0.35 cm/day^{0.5}. Default minimum rainfall for model reset (cm) is used here (= 0.5). Further, default parameters for numerical scheme to discretize Richard's equation are used here.

4.5.2 Soil hydraulic properties

In this thesis, soil types are grouped into two types of soil, light loamy soil and heavy loamy soil. These two soil types have different hydraulic properties. The light loamy soil is modeled with two layers, i.e. at the top loam (TL) and at the bottom loam (BL). Heavy loam is also modeled with 2 layers i.e. at the top clay (TC) and at the bottom is loam (BL). The soil of hydraulic functions of the soil layers to a depth of 4 m (the depth of soil domain chosen here) and soil water retention parameter was taken from Van Genuchten-Mualem parameters (i.e. saturated moisture content (ϕ_{sat}), residual moisture content ϕ_r , saturated hydraulic conductivity K_s , and shape parameters n , α , and λ were obtained from Wosten et al., 1994)). The parameters used to define the soil hydraulic properties of top soil loam (TL), top soil Clay (TC) and sub soil loam (SL) is shown in table 5.3 below.

Soils	ϕ_{res}	ϕ_{sat}	K_{sat}	α (cm-1)	λ (-)	n (-)
(Top) Loam	0.01	0.43	2.25	0.0096	-2.733	1.284
(Top) Clay	0.1	0.42	1.17	0.0118	-4.795	1.224
(Sub) Loam	0.01	0.49	2.22	0.0107	-2.123	1.28

Table 4.3 Top and sub soil properties

Soil Geometry and Texture

The soil in the area of study is simply modeled with 2 layers, i.e. top layers (14 cm thick) are divided into 10 compartments (vertical discretization) with 1 cm thick plus 2 compartments with 5 cm thick. The sub soil layer is modeled with 44 compartments with 5 cm thick and 18 compartments with 10 cm thick. The soil texture is defined as shown in figure 5.1

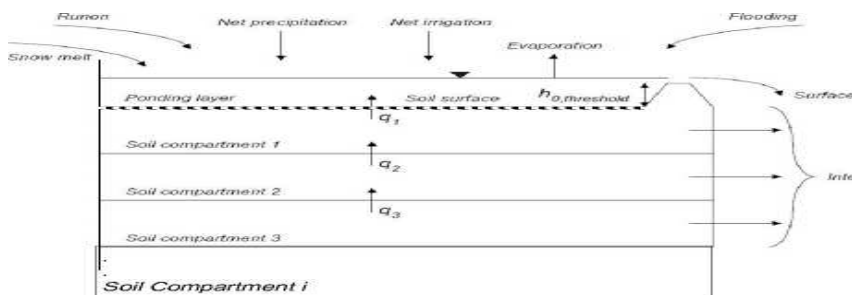


Figure 4.1. Geometry of soil profile and soil texture defined here

4.6 Drainage and bottom boundary

In this thesis, the depth of water level and the depth of the bottom of the ditches for the selected areas obtained from GIS map are not available in WWDSE design report. And the ground water level as stated in limitation sub topic of this paper is not available here also the exact values of drainage resistance and infiltration resistance are very difficult to determine. These values strongly depend on the phreatic groundwater level and drainage. Hence, here, no simulation of drainage is selected.

4.7 Yield of sugarcane

According to the WWDSE design report and other researches on technical inefficiency of sugarcane yield the three years calculated and tabulated below. even though the area of sugarcane plantation is

Year	predicted Yield*1000 ton	Area of Plantation	Sugarcane yield/Area	Actual yield*1000 ton
2014	3256	25000	123.2	2572.24
2015	3481	25000	146.8	2680.37
2016	3279	25000	131.16	2459.25

Table 4.6 Investigated yield of sugarcane from research (zinabu wolde)

5 Results and Discussion

This chapter presents the results and discussion of the field observed and simulated soil water balance components by CROPWAT model and SWAP model. The components of soil water balance considered and measured were; daily evapotranspiration (ET), transpiration (T), and, potential evapotranspiration, actual transpiration and irrigation requirement. The result with comparison of yield of sugarcane of these same soil water balance components as simulated using the two models is also presented. Based on the meteorological data for future climate as described above, prediction crop yield and water demand could be carried out by taking the other input parameters the same as described earlier.

As described earlier, this thesis aims to calculate water demand in the Kuraz project area in response to climate change and land transformation in the future in order to maintain maximum sugarcane crop yield.

From the research done on omo gibe basin higher emission scenario the basin will face drought condition and due to increased temperature the evaporation condition of the basin will be high. The current mean annual maximum and minimum temperature is expected to rise by about from 0.9 0c to 1.80c and 1.20c to 2.2 0c as the result for 0.2 0c raise in mean annual surface air temperature is expected in the future in average.

Research on land use and cover change on stream flow shows the surface runoff was increase by 87.475 m³/s in the wet season and decrease by 25.66 m³/s in the dry season from 1987 land use land cover to 2003 land use land cover according to the research done on land use land change effect on the sub basin runoff and discharge and sedimentation effect. Thus sedimentation effect will be high in decreasing the amount and head of water supplied for irrigation, it is important to calculate how much this design discharge will be affected by decrease of the amount of river and increase of sedimentation so first let see the effect of sedimentation and then we will estimate how much water will decrease in the canal.

5.1 Crop water requirements simulated using CROPWAT

The results from model execution included of crop water requirement and irrigation requirement and are presented in the following tables

Month	Decade	Stage	Kc	Etc	Etc	Eff rain	irr.req
	Coeff	mm/day	mm/dec	mm/dec	mm/dec		
Jan	1	Init	0.3	1.22	12.2	11.1	1.1
Jan	2	Init	0.3	1.22	12.2	11.3	0.9
Jan	3	Init	0.3	1.26	13.9	10.8	3.1
Feb	1	Init	0.3	1.3	13	9.3	3.6
Feb	2	Init	0.3	1.33	13.3	8.4	4.9
Feb	3	Init	0.3	1.33	10.6	11.7	0
Mar	1	Deve	0.34	1.5	15	14.8	0.2
Mar	2	Deve	0.42	1.88	18.8	17.3	1.4
Mar	3	Deve	0.51	2.28	25.1	22.5	2.6
Apr	1	Deve	0.6	2.68	26.8	30.3	0
Apr	2	Deve	0.69	3.07	30.7	36.3	0
Apr	3	Deve	0.77	3.31	33.1	31.7	1.3
May	1	Deve	0.86	3.51	35.1	25.8	9.3
May	2	Deve	0.94	3.68	36.8	22.3	14.5
May	3	Mid	1.03	4	44	19.7	24.4
Jun	1	Mid	1.07	4.11	41.1	16.3	24.9
Jun	2	Mid	1.07	4.09	40.9	13.1	27.8
Jun	3	Mid	1.07	3.98	39.8	13.7	26.2
Jul	1	Mid	1.07	3.88	38.8	14.5	24.2
Jul	2	Mid	1.07	3.77	37.7	14.6	23.1
Jul	3	Mid	1.07	3.77	41.4	15.1	26.3
Aug	1	Mid	1.07	3.77	37.7	15.9	21.7
Aug	2	Mid	1.07	3.76	37.6	16.5	21.1
Aug	3	Mid	1.07	3.95	43.4	15.6	27.8
Sep	1	Mid	1.07	4.13	41.3	14.1	27.2
Sep	2	Mid	1.07	4.32	43.2	13.1	30.1
Sep	3	Late	1.06	4.29	42.9	14.3	28.6
Oct	1	Late	0.93	3.78	37.8	15.9	21.9
Oct	2	Late	0.76	3.13	31.3	17	14.3
Oct	3	Late	0.63	2.54	17.8	10.8	0.8
Sum		0	23.11	90.84	913.3	503.8	413.3

Table 5.1 Result of irrigation requirement calculated with CROPWAT model

Year	SWAP actual ETO	cropwat ETO	SWAP irr. Req.(mm/dec)	CROPWAT irr. Req.(mm/dec)	Difference ETO	Difference in irr.req
2014	104.029	90.84	453.127	413.3	13.189	39.827
2015	112.656	102.245	462.87	420.32	10.411	42.55
2016	124.56	113.24	473.284	432.21	11.32	41.074

Table 5.3 comparison between CROPWAT and SWAP on irrigation requirement for sugarcane.

Due to the limited available data on sugarcane crop, a simple crop yield model is chosen for the SWAP model described here. With the simple model, SWAP could calculate the relative crop yield. This is realized by taking the ratio between the actual transpiration (T_a) and the potential transpiration (T_p), i.e. relative crop yield ($Y_a/Y_p = (T_a/T_p)$). To obtain the average relative yield for the entire area of Kuraz project area, the average relative crop yield for all the point of interests is taken. To be able to compare the yield response of the SWAP model and the data obtained from WWDSE.

Despite all the simplification used in the SWAP model, it still could capture some trends of the relative sugar cane yield in the kuraz area. The limitation of this model in predicting the relative crop yield is discussed further.

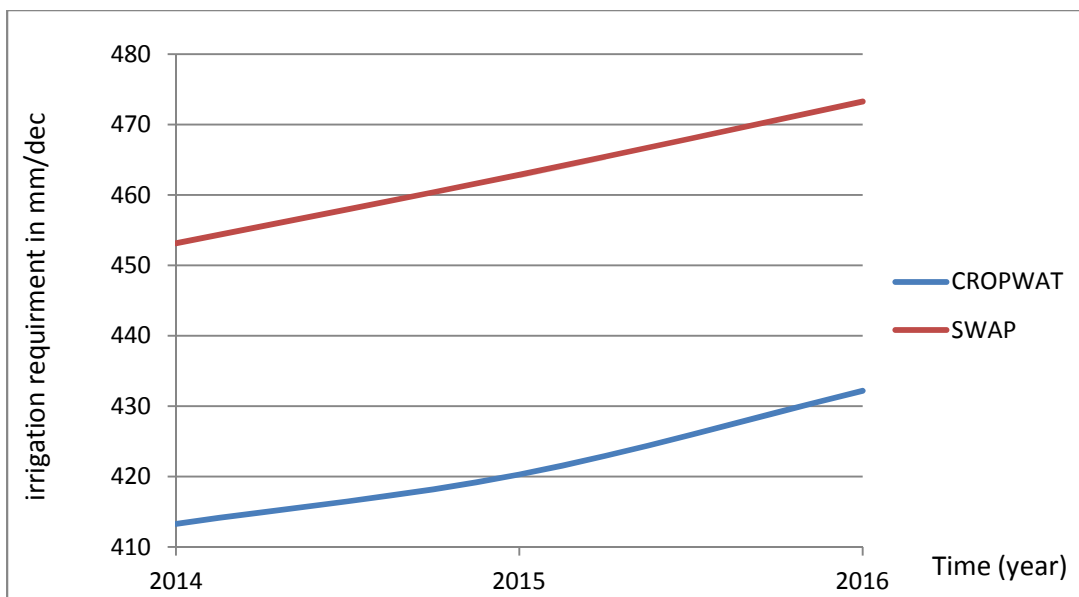


Figure 5.1 Simulated irrigation requirement by CROPWAT and SWAP model

As described earlier, the SWAP model presented here requires many parameters as input, i.e. meteorological data, irrigation parameters, crop parameters, soil properties, drainage parameters, and bottom boundary conditions. The meteorological data that were used in the SWAP model presented here are available from National meteorological agency and WWDSE design report. For fixed irrigation input data, data from WWDSE design report was used,

For each growing stage k the actual yield $Y_{a,k}$ (kg/ha) relative to the potential yield $Y_{p,k}$ (kg/ha) is calculated in SWAP model using the following equation:

$$1 - \frac{Y_{a,k}}{Y_{p,k}} = K_{y,k} \left(1 - \frac{T_{a,k}}{T_{p,k}} \right) \quad 6.1$$

Where $K_{y,k}$ is the yield response factor of growing stage k , and $T_{p,k}$ (cm) and $T_{a,k}$ (cm) are the potential and the actual transpiration respectively, during growing stage k . For the SWAP model defined here, a simple crop yield model is used. The value of potential and actual transpiration can be calculated by using SWAP model. However, the value of crop yield response factor (K_y) should be given (input data) in the model. Crop yield response is a function of the age of the sugar cane plants, the type of the species, irrigation method and management and the growth stage due to the changes in meteorological data (van Dam, 1997).

In the SWAP model for sugarcane crop presented here, a simple model is chosen. This is because mostly parameters needed to apply detailed crop model are unknown. In the crop simple model, the yield response factor of the whole growing stage is assumed to be equal to 1 (as suggested by van Dam, 1997). By using the simple model for crop yield, the relative crop yield for each point of interest in the Kuraz project area could be calculated.

In order to enable better sugar cane crop yield prediction, it is recommended to use the detailed crop yield model available in SWAP, however this requires effort to measure all the parameters needed to determine crop yield response factor (K_y). This is not a straight forward task and will require significant effort.

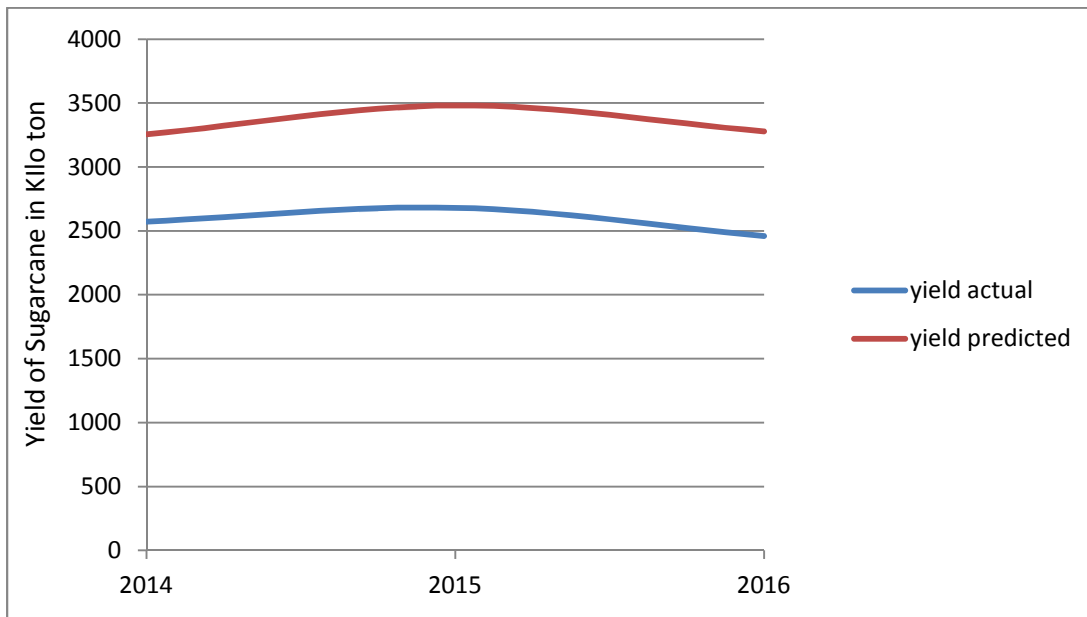


Figure 5.2 comparison of actual and predicted yield of sugarcane

As described above, the SWAP model for sugarcane crop plantation in Kuraz project area has been validated using the available data. Therefore, this model can be further utilized to predict water demand in the future (i.e. 2020) in order to maintain optimum sugarcane crop yield. This can be realized by providing the predicted future meteorological data into the SWAP model with the input parameters that has been validated model. It can be concluded with the estimation of water demand in the future which is useful information for Sugar Corporation in order to ensure sufficient water supply to kuraz project area.

5.4 Discussion on Model calibration (Crop yield) and further application

If the amount of water supplied to Kuraz irrigation project area could be maintained in the similar level as it is today, based on the calculation presented here, then in the future the capability of the corporation to satisfy water demand is not enough. However, taking into account all the simplification and the uncertainties in the model, it is safer for the corporation to increase the water supply capability in the future, particularly using a better approach of soil and water management integrated with sub basin scale soil and water conservation practices which we have been discussed in the previous chapters, in order to cope with the increasing water demand in the future.

The water demand needed to maintain good soil moisture and yield optimum sugar cane yield as calculated in SWAP is increased. The extreme water demand is due to the fact that the average maximum temperature in summer is higher. The SWAP model described here showed, as expected, that water demand is higher.

According to WWDSE design report, the water balance modeling was done in order to check the capacity of Omo River in respect to satisfying the water requirement of kuraz irrigation project and maintain the channel flow downstream of diversion point. accordingly the result of analysis showed that without gibe III operation the omo river doesn't satisfy the irrigation demand for some months in case of the second scenario the release of the regulated flow from Gibe III HP dam is considered the power release fluctuate from 335 to 950 m³/s which means that the minimum release could satisfy the irrigation water requirement of the 175,000 ha of land that planned to be cultivated under sugar development.

So the need for estimation future water demand under climate change especially drought happening with the increase of temperature and siltation due to land degradation which affect the water supplied for irrigation is important to find adaptation strategy. Increasing the crop water requirement through transpiration and decreasing the amount and head of the canal water supply respectively is then possible through adaptation option.

6 Conclusions, Recommendation and Areas of Further Research

6.1 Conclusion

The purpose of this study is to develop a better understanding of how farmers and irrigators perceive and use climate, plant growth and soil information to assist in their irrigation schedule decision making. This is to ensure that when scientific information is provided to assist irrigators, it is presented in such a way this is useful and encourages uptake. The benefit is to both the irrigators and the service providers as maximum benefit is being gained from such services. Key areas for improvement have been identified in this study like water losses should be reduced and water savings and efficiency should be increased, in particular in agricultural water scarce areas.

Different assessments have revealed that there are many factors that influence the acceptance of better irrigation information by early adopters. Some factors can be improved or modified by the scientists providing the information. These factors include how easy the information is to understand, how realistic it appears to be, how specific is the information to each farm and how integrated is the information (water quality, quantity, climate, soil, land use, etc) with each other.

Land and soil management approaches aimed at combating soil erosion, preventing loss of soil organic matter, sequestering soil carbon and improving water retention are critical for long-term sustainability of farming and healthy ecosystems. The corporation should play a role in promoting these approaches, but farmers and national and regional administrations should also initiate action.

In this thesis, I have shown the potential impacts of current and future climate change combined with agricultural land use change scenarios on the south omo sub basin agricultural water management specifically kuraz irrigation project area. The first general conclusion is that overall the crop yield simulated in the watersheds will be decrease in the future. The second general conclusion is that simulated adaptation management strategies at the farm level and sub basin level are able to mitigate the combined impacts of climate and land use change, and also can improve agriculture water management efficiency as modeled the kuraz irrigation project.

Further research should entail applying agro hydrological models using parameter non-uniqueness to provide an even greater global indication of the uncertainty. The uncertainty in the reported outcomes is therefore correspondingly high, and the results must be interpreted with caution. I have put an option that was current and most suitable to provide some

indication of the direction and the magnitude in which agricultural water management may be impacted and adapted by future changes.

Controlled standards are also necessary to improve the calibration and validation of the crop parameter component of the SWAP model. Agricultural land management action for the provision of sustainable outcome and recommended option for Sugar Corporation should be developed through research and integrated management, though there is no such program and plan in the sub basin. According to the point of further research places put on the WWDSE design report: Water allocation, system performance and conjunctive use of surface and ground water and irrigation policy measures are necessary to focus on with this direction.

From this study of assessing the impact of climate change and land transformation in the future agricultural water need, specifically on sugarcane crop yield and water demand in the area of Kuraz project in sub basin, the following conclusions can be drawn:

SWAP model for sugarcane crop plantation is presented and calibrated. The model presented here is able to show the impact of climate change and land degradation on increasing water demand in order to maintain optimum sugarcane crop yield for the past least years. The result of the model also shows due to climate change effect particularly temperature increase and land transformation effect particularly increase of siltation in the canal and discharge decrease in the river channel the sugarcane yield will decrease and the demand of water to balance this effect will increase in the future. Consequently the result of the model, even is uncertainty of result data is high due to shortage of data in the project area, can be an support for the effect of climate change and land transformation in agricultural water management which target is increase of crop yield in agricultural land. Thus we can conclude also from the experimental case study the need for improved agricultural water management which can adapt the effect of climate change and land transformation as we discussed in the previous chapters.

In south omo gibe basin there is a shared vision by the State and the private sector, which is to become an agricultural food power. This vision generates needs for research that have been partially addressed by the national scientific community further in this direction. However, this investigation brings forth new have been partially questions on the interactions among agriculture-water resources, society and environment. This leads us to affirm that investigation on agricultural water management is actually an open field full of questions and opportunities, and this investigation must consider local, national and international aspects, on a highly dynamic scenario.

The scientific guide subject of this paper enhance the establishment of models that help in taking decision carefully and rapidly about actions to rehabilitate sugarcane product and environment with a participative spirit.

However, after evoking the preponderant problems in the sub basin (soil and irrigation water salinity, agro-pedagogical constraints, water table rising, hydro-agricultural problems) I have presented different approach to describe the water, nutrient and salt distribution in different type of soil, under irrigation systems that can be utilized inside the sub basin and for all type of plants. Equations presented can be used to monitor the ascent of water table at different time scales and to foresee the period to pull down its level according to phonological stage of plant.

The change in bottom flux from groundwater recharge into capillary rise can be a threat for the sustainability of the system in terms of falling groundwater tables and salinity. The drop in groundwater might be limited as a large part of the basin is not irrigated and water from these areas recharge the groundwater resources. Salinity can become a real threat in the future as the drought continues, although lateral fluxes are still quite high. Further research in terms of scenario analysis is desirable. This study shows that, using only readily available secondary data (standard meteorological data, soil map and land use map) and a physically based simulation model, we can provide swift information about the functioning of a system. Although not all the available data was in exactly the required form, it was more attractive to convert the existing data to the form required than to operate a time-consuming and expensive field measurement campaign. This approach was illustrated by the conversion of soil texture data into soil hydraulic data, such as retention and conductivity curves. Another example was the application of irrigation fee data establishing irrigation advisory, in combination with a map of the tertiary units, to produce spatially distributed data for crop.

6.2 Areas of Further Research

As described in chapter 4, the main limitation of the SWAP model presented here is the crop yield response factor. In this study the crop yield response factor (K_y) is assumed to be 1 for the whole growing period. To enable better prediction of crop yield potential a study (and field work) needs to be carried out in order to accurately determine the crop yield response factor and to fulfill all other data needed to simulate detailed crop model for sugarcane crop.

Due to temperature increase predicted (based on climate change scenario), the water demand in the Kuraz project area will be increasing as well. This will imply that the potential water shortage will increase. Further innovation of growing a sugarcane crop with less water demand such as deficit irrigation, optimum amount of sugarcane plants per hectare by reducing sugarcane plantation area to ensure enough water supply for other crops and gain higher water productivity, new optimum irrigation schedule (amount and timing) and water distribution system, etc needed for better agriculture water management. If the correlation between remote sensing data and the crop yield could be established, then the remote sensing method to calculate biomass and predict potential crop yield can be used to regulate the right amount of irrigation (water demand) in the Kuraz project area.

To get better estimation of irrigation demand for agricultural purposes, it is important to have irrigation monitoring of how much actual irrigation water applied in the Kuraz irrigation project area. With this observed data a better prediction of potential and actual crop yield and irrigation schedule could be simulated by the SWAP model.

When using SWAP model the necessity of field test in addition to laboratory test will have best result integrating with remote sensing to check parameters of the model like salt and nutrient content at different places in the field and integrate with the model to predict the movement of solutes and heat in the soil. In the same way we can check crop development stage and predict the phenomenon of rainfall and temperature also potential of the area for irrigation.

But still the challenges are lack of soil database and even if in these paper laboratory data are used as an input for the model SWAP can simulate with variety of soil characteristics but through field tests specifically SWAP has a potential to simulate the ground water level fluctuation, however in this paper as it is stated on the limitation, no ground water data is available.

Soil salinity prediction monitoring and mapping using modern technology and the need for using of electrode for measuring soil salinity and lysimeters for measuring the soil moisture content of the soil is better if used and integrated with GIS and remote sensing technology when modeling using SWAP. Soil salinity prediction monitoring and mapping using modern technology should also include how the impact can be quantified after assessing the effect to identify the adaptation strategy. Tube well technology which advances agricultural water management is also important to measure ground water level which is an input data for SWAP model as stated earlier, and this data can be integrated with remote sensing technology through model like MODFLOW.

Furthermore, works in coordination with specialists in the development of new techniques and methodologies to be applied to an understanding of the physical environment are important. Some of the better developed lines of research within this field are crop monitoring, detection of land cover alteration and estimation of evapotranspiration through remote sensing.

An agro-hydrological simulation model is useful for agriculture monitoring and Remote Sensing provides useful information over large area. Combining both information by data assimilation is used in agro-hydrological modeling and predictions, where multiple remotely sensed data, ground measurement data and model forecast routinely combined in operational mapping procedures. Remote sensing cannot observe input parameters of agro-hydrological models directly. Remotely sensed ET data and ground measurement data from experiment fields were then combined in a data assimilation to estimate parameters of the SWAP model. The system is initialized with a population of random solutions and searches for optimum by updating generations and the reasonable parameters (sowing date and

harvesting date, Ground water level) can be estimated. On the basis of estimated parameters, soil moisture is predicted by SWAP model. The agro-hydrological model driven by the observed ET produces reasonable water cycle states and fluxes, and the estimates are moderately improved by assimilating ET measurements that provides information on the surface soil moisture state,

6.3 Recommendation

Even though the effect of climate change and land degradation has an effect on the yield of sugarcane which affect production and productivity, the sugar corporation participation is limited on this area and less efforts is seen on soil and water conservation work by the corporation like terracing, afforestation and nutrient management. Using of ground water saving, storage of water during rain and additional storage infrastructure through technology like pipes and sprinkler is also not observed in the sub basin for improved agricultural water management.

Consequently, combination and integration of a number of technical, institutional, and economic improvements should be considered in the future and further research should cover a broad range of options for improving water productivity.

Research institutions should forge partnerships with the Government and private sector, which is extremely active in development of irrigation technology. The challenge will be to bring private research down to the level of the needs of investor in developing countries and to get affordable technology.

There should be Sectoral Evaluation and Strategies for Improvement which target to avoid water scarcity and pollution. Every region has its natural, economic and socio-cultural preconditions and requires different reasonable measures in order to establish a sustainable and integrated water resource management. Regional boundary conditions such as distribution of precipitation, characteristics of the main water bodies as simulated for the different scenarios.

Adaptation measures would not be achieved without creating public awareness as means to knowledge transfer and to helping organization and people develop attitudes necessary to adopt practices and formulate new positive behavior patterns towards water conservation through community mobilization and sensitization. Although the problem of water scarcity had been recognized at the community level, however, transfer of knowledge and technology would be needed to implement as adaptation measures.

The main reason for not adopting water saving measures by the farmers and organization is the lack of incentives to save water. Water saving can be encouraged by supporting institutions, providing incentives and information, financial assistance and coordination.

Several complementary approaches must be promoted. First, water savings and more efficient use of water should be achieved through water metering, improving irrigation efficiency, reducing leakages to a sustainable economic leakage level, and irrigation scheduling. In particular, water metering should be introduced and enforced via water policies, and could potentially target water scarce areas or water-intensive cropping systems. Second, improved water availability should be achieved through water re-use, rainwater harvesting and storage.

Improved land and soil management approaches will provide important water benefits. Policies that encourage sustainable use of shallow groundwater to buffer inter-annual droughts and supply shortages will offer the most scope for autonomous adaptation, but pose some major challenges in the design of regulatory and incentive structures that ensure equity and long-term resilience. In the short to medium term, modernization strategies for irrigation systems should aim to minimize capital investments, and seek the most cost-effective options in water control.

In Summary giving attention on a) Promoting an integrated vision of water resources at the basin; b) Strengthen the management ability of the users organizations; c) Strengthen the management and institutional operation of the extra property irrigation infrastructure; d) Generate the coordination to improve the market of water resources for irrigation; e) Control environment pollution caused by irrigation.

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Annex

Annex 1 an example of a meteorological data (year 2014) obtained metrological station.

Station	Day	Moith	Year	Radiation	T min	T max	Humidity	wind speed	Precept	evapo transpiration
Kako	1	1	2014	521.69	0.98	31.46	67.95	3.77	22.54	6.47
Kako	2	1	2014	520.77	16.60	29.25	63.18	3.51	7.78	5.56
Kako	3	1	2014	520.83	16.60	29.40	63.50	3.53	25.87	5.63
Kako	4	1	2014	520.83	15.68	29.40	63.50	3.53	7.78	5.63
Kako	5	1	2014	521.44	16.17	30.87	66.68	3.70	1.86	6.23
Kako	6	1	2014	520.77	17.15	29.25	63.18	3.51	7.78	5.56
Kako	7	1	2014	521.32	16.60	30.58	66.04	3.67	1.18	6.11
Kako	8	1	2014	520.77	16.60	29.25	63.18	3.51	34.59	5.56
Kako	9	1	2014	521.89	17.84	31.95	69.01	3.83	7.78	6.67
Kako	10	1	2014	520.77	16.60	29.25	63.18	3.51	30.30	5.56
Kako	11	1	2014	521.36	16.60	30.67	66.26	3.68	11.56	6.15
Kako	12	1	2014	520.91	18.13	29.60	63.93	3.55	59.16	5.71
Kako	13	1	2014	520.77	16.60	29.25	63.18	3.51	0.98	5.56
Kako	14	1	2014	520.87	16.60	29.50	63.72	3.54	119.77	5.67
Kako	15	1	2014	521.69	18.91	31.46	67.95	3.77	7.78	6.47
Kako	16	1	2014	520.77	16.60	29.25	63.18	3.51	75.95	5.56
Kako	17	1	2014	521.12	19.70	30.09	64.99	3.61	7.78	5.91
Kako	18	1	2014	520.77	16.60	29.25	63.18	3.51	45.37	5.56
Kako	19	1	2014	520.91	19.89	29.60	63.93	3.55	8.82	5.71

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Kako	20	1	2014	521.32	16.60	30.58	66.04	3.67	7.78	6.11
Kako	21	1	2014	520.77	20.09	29.25	63.18	3.51	75.71	5.56
Kako	22	1	2014	521.03	16.60	29.89	64.56	3.59	2.94	5.83
Kako	23	1	2014	520.77	20.87	29.25	63.18	3.51	43.69	5.56
Kako	24	1	2014	521.36	16.60	30.67	66.26	3.68	5.39	6.15
Kako	25	1	2014	520.77	18.82	29.25	63.18	3.51	53.72	5.56
Kako	26	1	2014	521.32	16.60	30.58	66.04	3.67	7.78	6.11
Kako	27	1	2014	520.77	16.60	29.25	63.18	3.51	53.94	5.56
Kako	28	1	2014	521.48	19.11	30.97	66.89	3.72	7.78	6.27
Kako	29	1	2014	520.77	16.60	29.25	63.18	3.51	32.42	5.56
Kako	30	1	2014	520.77	19.89	29.25	63.18	3.51	7.78	5.56
Kako	31	1	2014	520.84	16.60	29.42	63.55	3.53	84.67	5.63

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Annex 2 Selected boreholes and their physical properties from laboratory test result of WWDSE

Parameter	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-
	TP-18	TP-20	TP-43	TP-53	TP-54	TP-55	TP-56	TP-57	TP-58	TP-59
	0.7-3.0	0.7-3.0	0.8-3.0	0.4-3.0	0.1-3.0	0.3-3.0	0.6-3.0	0.4-3.0	0.4-3.0	0.6-3.0
	Lab No: 547/08	Lab No: 548/08	Lab No: 549/08	Lab No: 550/08	Lab No: 551/08	Lab No: 552/08	Lab No: 553/08	Lab No: 554/08	Lab No: 555/08	Lab No: 556/08
Specific gravity	2.66	2.69	2.7	2.68	2.64	2.66	2.72	2.81	2.61	2.63
Grain Size Analysis										
Clay %	54.87	25.77	83.07	24.33	30.07	65.85	34.46	43.5	39.37	55.25
Silt %	42.41	66.91	12.63	64.41	44.57	23.11	54.64	43.92	45.73	35.81
Sand %	2.72	7.32	4.3	11.26	25.36	11.04	10.9	12.58	14.9	8.94
Gravel %	-	-	-	-	-	-	-	-	-	-
Atterberg Limits										
Liquid Limit	74.45	78.7	115.6	48	68.8	90.5	82	78.2	91.5	84.5
Plastic Limit	35.72	36.17	36.53	26.52	27	33.94	34.08	28.9	31.18	32.82
Plastic	38.73	42.53	79.07	21.48	41.8	56.56	47.92	49.3	60.32	51.68

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Parameter	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-	KRB MC-
	TP-18	TP-20	TP-43	TP-53	TP-54	TP-55	TP-56	TP-57	TP-58	TP-59
	0.7-3.0	0.7-3.0	0.8-3.0	0.4-3.0	0.1-3.0	0.3-3.0	0.6-3.0	0.4-3.0	0.4-3.0	0.6-3.0
	Lab No: 547/08	Lab No: 548/08	Lab No: 549/08	Lab No: 550/08	Lab No: 551/08	Lab No: 552/08	Lab No: 553/08	Lab No: 554/08	Lab No: 555/08	Lab No: 556/08
Index										
Standard Proctor										
MDD (gm/cc)	1.277	1.205	1.19	1.386	1.325	1.215	1.238	1.257	1.305	1.19
OMC (%)	36.05	41.5	43	32.3	33.5	42.5	37.5	35	34	44.3
Direct Shear										
C(kPa)	40	39.67	46.67	30.67	39.67	37	49	44	37	58
F (0)	13.49	10.2	13.77	13.22	20.56	10.2	19.79	19.79	13.77	18.26
Permeability, cm/sec	1.43X10 ⁻⁸	2.35X10 ⁻⁸	2.52X10 ⁻⁸	1.350X10 ⁻⁶	4.3X10 ⁻⁸	7.45X10 ⁻⁹	1.32X10 ⁻⁷	6.01X10 ⁻⁹	4.12X10 ⁻⁸	3.380X10 ⁻⁷