Impact of Climate Change on Irrigation

Case Study on: Wonji Shoa Sugar Plantation Estate

MSc Thesis

By

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This is to certify that the Thesis prepared by Bizuayehu Abera entitled "impact of climate change in irrigation case study on Wonji Shoa Plantation Estate" in partial fulfillment of the requirements for the degree of Master of Science (Hydraulic Engineering) compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Signature

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Table of Contents

Contents **Pages**

List of Tables **Pages**

List of Figures Pages

Acronyms

AOGCMs	Coupled Atmosphere-Ocean General Circulation Models
ARB	Awash River Basin
CAF	cane after fallow
CMIP	Coupled Model Inter comparison Project
CORDEX	Coordinated Regional Climate Downscaling Experiment
CSM	Crop simulation models
ESDMs	Empirical statistical downscaling models
FAO	Food and Agriculture Organization
GCM	general circulation model
GWTD	ground water table depth
IAMs	Integrated Assessment Models
iPCC	Intergovernmental Panel on Climate Change
LOCA	Localized Constructed Analogs method
MER	Main Ethiopian Rift
NAST	National Assessment Synthesis Team
NCA	National Climate Assessments
NMSA	National Meteorological Services Agency
RCM	regional climate model
RCP	representative concentration path way

SA	Scientific Assessment
SREP	Special Report on Emissions Scenarios
UNFCCC	United Nations Framework Convention on Climate Change
USGCRP	Climate Science Special Report: Fourth National Climate Assessment
WCRP’s	World Climate Research Programme’s
WMO	World Meteorological Organization
WP	water productivity
WSSE	Wonji–Shoa Sugar Estate

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Abstract

Irrigation is significant in increasing agriculture production and productivity for sustainability of country's economy. Impacts on existing activities for irrigation design and management system is obvious due to rapid change of climate system which raised the concern of floods and droughts. This paper future focus the impacts in irrigation system on Wonji Shoa Suger Plantation Estate. The assessment is founded on downscaled outputs of Cordex Africa climate data portal and a sugarcane growth model. A range of impacts on water resource systems results from change of local hydrologic condition are because of climate changes. Every aspect of human well-being will be hurt by such changes. The thesis objective is to evaluate the influence of changing climate on the crop yield and irrigation requirement for Wonji Shoa Sugarcane Plantation Estate. For future climate data, it used the results of projections of cordex regional climate model (RCM) with bias correction for medium concentration representative path way 4.5RCP and high concentrative representative path way 8.5RCP scenario. The down-scaled data were then used as input to the AQUACROP model to simulate the corresponding future yield, irrigation requirement and evapotranspiration. The analysis done for the 2020s (2010–2039), the 2050s (2040–2069) and the 2080s (2070–2099), and it compared them with the reference period (1990–2016) using measured and modeled data. The time series generated by downscaled RCM indicate a significant increasing trend in maximum and minimum temperature values and a slight increasing trend in precipitation for both 4.5rcp and 8.5rcp scenarios for all three bench mark periods. The yield and irrigation requirement impact analysis made with the downscaled temperature and precipitation time series as input to the Aquacrop model suggested for both 4.5rcp and 8.5rcp scenarios. The model output shows that there is an annual increase in yield. For 8.5 rcp scenarios, the incensement is 6.2%, 7.84, 11.03% and 14.48% in 2020s, 2040s, 2060s and 2080s respectively. For 4.5 rcp scenarios the increment is much lower compared to 8.5rcp scenarios. But there is steel increasing in yield for 4.5rcp. The change is 0.3%, 1.8%, 7.02%,and 4.82% for the period of 2020s, 2040s, 2060s, and 2080s respectively. The evapotranspiration shows an increases in 20.34%, 20.12%, 23.59% and 24.36% for 8.5 rcp in the period of 2020s, 2040s, 2060s, 2080s respectively. For 4.5rcp scenario the *change is in about 8.4%, 11.65%, 13.22%, and 15.85% for the period of 2020s, 2040s, 2060s, and 2080s respectively. In irrigation requirement, for 4.5 rcp scenarios there is no change in four benchmark periods and in decreases after 2060s for 8.5 rcp scenario in -.816% and -9.75%.*

Keywords; Coordinated Regional Climate Downscaling Experiment; Regional Climate Model; Representative Concentration Path way; AQUACROP;WONJISHOA,

1. INTRODUCTION

1.1 Background

Global climate inconsistency and change caused by natural processes and anthropogenic factors may result in major environmental subjects that will affect the world during the 21st century. Any increase in global warming is expected to affect human health, with primarily negative consequences. Lower risks are projected at 1.5°C than at 2°C for heat-related morbidity and mortality and for ozone-related mortality if emissions needed for ozone formation remain high. Urban heat islands often increase the impacts of heat waves in cities. Risks from some vector-borne diseases, such as malaria and dengue fever, are projected to increase with warming from 1.5°C to 2°C, including potential shifts in their geographic range (Bazaz, Bertoldi et al. 2018). Rising global average temperature is associated with widespread changes in weather patterns. Surface temperature is projected to rise during the 21st century under all assessed emission scenarios. The global mean surface temperature change for the period 2016–2035 relative to 1986–2005 will *likely* be in the range 0.3 °C to 0.7 °C (Pachauri, Allen et al. 2014). In Ethiopia, observations show a year-to-year variation for rainfall events in all over the country (Zerga and Gebeyehu 2016). While regional models predict increase in rainfall, higher resolution analyses for Ethiopia suggest with spatial differences, there are both increases and decreases in the overall rainfall averages. An increase in the rainfall inconsistency is also predicted, with a rising frequency of both extreme flooding and droughts that could seriously affect agricultural production. Mean annual rainfall in Ethiopia is projected to increase, mainly as a result of increasing rainfall in the short rainy season (October to December) in southern Ethiopia. Projected changes in the April to June and July to September rainy seasons are mixed – the tendency is towards a small increase in the south (especially in the south-west) and a decrease in the north-east. The April to June and July to September rainy seasons affect large portions of Ethiopia (Simane, Beyene et al. 2016) .

The challenges faced by the agricultural sector under the climate change scenarios are to deliver food security for an increasing world population while protecting the environment and the functioning of its ecosystems. Climate change has become significant threat to agriculture and food security across the globe. Projected changes in temperature, precipitation and CO2 concentration are expected to significantly impact crop productivity (Hossain, Qian et al. 2019). Erratic temperature and precipitation conditions are shown to often occur concurrently, with dry growing seasons more likely to be hotter, have larger drought indices, and have larger vapor pressure deficits. This leads to the confluence of a variety of climate conditions that negatively impact crop yields. These results show a consistent increase in global agricultural exposure to negative climate conditions since 1980 (Zhu and Troy 2018).

Sugarcane (*Saccharum* spp. hybrids) is tropical grass broadly grown in both hemispheres in over 120 countries worldwide. It is an important agro industrial cash crop, providing raw material for different sugar industries and plays crucial role in the economy of several countries (Sanghera, Malhotra et al. 2019). Ethiopia is among the country's which are struggling to cover their need (by two old plantations in Wonji and Methara under irrigation and unfinished sugar industry projects). There is high demands for sugar all over the country and the world though we can't cover even the country need. All crop production climaxes the importance of the weather in this case sugarcane production. Knowledge about the weather hence is very important. The current changing climate has high influence for the country like ours so, the adaptation of farming systems to climate change demands to take advantage of the potential benefits and minimize potential adverse impacts to crop production. Many study has made by using crop models to assess sugarcane responses to future climate scenarios all over the world , but no such study has been done for Ethiopia until now. This paper simulated the impacts of climate change on sugarcane in wonji shoa plantation using the Aquacrop model and a range of two projected downscaled climate scenarios, to estimate the likely future impacts on the crop in terms of yield and irrigation water requirement

Ethiopia has twelve river basins, out of which the Awash River Basin (ARB) is intensively used and environmentally susceptible .The ARB is most utilized and developed basins of Ethiopia; however, records and data accessibility are the major problems in this basin. The basin offers consistent irrigation water to larger and productive farming areas. Moreover, it generates hydropower energy and provides water supply for different towns and cities along its course, which includes Legadadi, Gefersa, Dire and Aba-Samuel reservoirs. A number of large and small irrigation schemes are found in ARB, which includes Wonji sugar factory and Wolenchiti (Tadese, Kumar et al. 2019). The increase in population growth, economic development and climate change have been proven by (Pachauri, Allen et al. 2014) to cause rise in water demand, drought and water scarcity. Since crop production is highly dependent on the climate of the surrounding environment, this study is used to assess the future variability crop yield and irrigation requirement under climate change, which such information would allow managers and producers to select cropping systems that ensure efficient use of water resources and result in adequate crop productivity.

In climate change impact studies, models are required to simulate sub grid scale phenomena, and such hydrologic models require input data at a similar scale. These data are generally provided by converting the GCM outputs into a reliable regional hydrologic time series at the selected watershed scale. The methods used to convert GCM outputs into local meteorological variables are usually referred to as ‘downscaling’ techniques. Downscaling makes use of systematic dependencies between local conditions and large-scale ambient phenomena in addition to including information about the effect of the local geography on the local climate (Benestad 2016).

In this study, the already downscaled GCM output and the atmospheric Circulation variables derived from the cordex model for RCP4.5and RCP8.5 scenarios used to show daily precipitation and temperature series for the Wonji Shoa. The climate scenarios observed then used to drive the AQUACROP model. Changes in the modeled crop yield and irrigation water requirement between current and future climate scenarios were compared and analyzed.

1.2 Statement of the Problem

Water, the most important natural resource, required for the survival of all living species. Management of water resources properly is important in satisfying current demands as well as maintains sustainability since existing amount of water is inadequate, scarce, and not spatially distributed in relation to the people requests. Water resources management and planning in current, 21st century, is becoming difficult due to the conflicting demands from various stakeholder groups, increasing population, rapid urbanization, climate change producing shifts in hydrologic cycles, the use of high-yielding but toxic chemicals in various land use activities and the increasing incidences of natural catastrophes. Now from recorded cause of difficulty's, problems rise from climate change have huge impact on life since it touch every single activities of human being. Therefore, influences of climate change in water resources are the most crucial research agenda in worldwide level (Pachauri, Allen et al. 2014).

The Awash River Basin is critically important to Ethiopia, in view of combination of huge growth potential and massive resource. Large population growth in Ethiopia will increase the demand for usual resources, primarily water between each region. Ethiopia is also under great pressure on economic expansion, deforestation, urbanization and climate change. Human activities of the catchments increased over the past century and expected to grow even more rapidly in the future; hence, management of water will become even more essential with a changing climate.

The Intergovernmental Panel on Climate Change's (Pachauri, Allen et al. 2014) findings suggests that developing countries like Ethiopia will be more vulnerable to climate change due to their economic, climatic and geographic settings. Climate change can affect multiple features of aquatic resources (e.g., quantity and quality, high and low flow extremes, timing of events, water temperature, etc). All these aspects affect livelihoods in the basin but have not received attention in planning for future water allocation and design of water infrastructures yet (Tadese, Kumar et al. 2019).

The Awash River Basin faces landed gradation, high population density, natural water degradation salinity and wetland degradation. Already desertification has started at lower Awash River Basin. In the high land part deforestation and sedimentation has increased in the past three decades. As more water is drawn from the river there could be drastic climate and ecological changes which endanger the basin habitat and human livelihood. Draining the wetlands for irrigation could imbalance the sustainability of the basin. Existing studies in world indicate negative effects of weather shocks on the livelihoods of small-scale farmers who are currently operating at a very narrow margin of profits and who lack access to financial resources and technological knowledge. Higher temperatures during the vegetation period may cause higher probability of drought risk and declining productivity of agricultural production which cause economic effect. Hence it is necessary to improve our understanding of the problems involved due to the changing climate.

Having the above mentioned and other related problems, it is imperative to understand effect of upcoming climate variation on hydrometeorology, subsequent influence on the lives of people and water resources. Model evaluation is also need to be carried out using observed data to verify accuracy. Downscaled scenarios of RCP4.5 and RCP8.5 and (Aqua Crop) model linked. Uncertainty analysis has been utilized in the study for evaluate climate changes impacts on the small scale irrigation of wonji shoa, Ethiopia.

1.3 Objective of the Research

1.3.1 General Objective

The overall objective of the research is to assess the impacts (in yield aspect) of climate change on agricultural production of irrigation using climate change scenarios and agronomic model (Aqua Crop).

1.3.2 Specific Objectives

- To analyzing the impact of a changing climate on crop yields of Wonji Showa plantation.
- Predict the consequences of this biophysical change (climate) at Wonji Showa plantation.
- Assess the impact of climate change on irrigation requirement

1.4 Limitation of the Research

Certainly, the approach developed in this study which has linked climate scenarios and crop modeling has limitations. This study does not take into account the possibility of future change in daily rainfall distribution within the seasons, or changes in the frequency of extreme events such as droughts, heat waves or cloudiness, which could considerably change the results discussed here.

In this study the impact of climate change was measured assuming the land cover will remain the same. However, in real world the land cover is dynamic due to natural and human influences. It is also assumed that the socio-economic condition in the area will remain the same.

In WonjiShoa sugarcane plantation estate, they use routine of sugarcane plant up to 5 times, different variety and different soil type but this study done in first routine, only one variety(N-14)with harvesting age of nearly12 month and major soil covering of the estate heavy soil are considered.

1.5 Thesis Outline

This thesis contains six chapters organized as follows. Chapter one gives a general introduction to the study with its objective. Chapter two describes the reviewed literature related to the study. Chapter three gives a brief description of the study area and data availability. Chapter four deals with the methodology adopted for the study. In Chapter five the results are shown and discussed. In chapter six conclusion and recommendation are presented.

2. LITERATURE REVIEW

2.1 Climate Change Science

Climate change discusses to any long-term major change in the expected forms of regular weather of a specific region or area or zone over properly significant period of time. It is long-term change in the statistical distribution of weather arrays over period of time that array from decades to millions of years.

Climate change may be restricted to a specific region, or may occur across the whole Earth. The factors that govern the climate at a location are the rainfall, sunshine, wind, humidity and temperature. Climate change may result from events such as burning fossil fuels, Greenhouse effect, deforestation, urbanization, desertification, volcanic eruption, flood, forest fire, storms etc.

Evidence shows that the Earth's climate is warming. Warming of the climate system in present decades is obvious, as is now evident from observations of rises in global average air and ocean temperatures, growing global sea level and widespread melting of snow and ice. Among the assessment that are carried out by the IPCC, the recent one which published in 2014, states the projected global warming by 2100 using the SRES scenarios as input, current models estimate universal temperature to rise by 1.4ºC to 5.8ºC and rainfall would vary up to ±20% from 1990 level (Pachauri, Allen et al. 2014).

2.1.1 Climate Change and Water Resources

Hydrologic cycle changes rise from climate change since different climatic system components including atmosphere, hydrosphere, cryosphere, land surface, and biosphere, are involved. Therefore, water resources affected by climate change both directly and indirectly (Singh, Mishra et al. 2014).

Water resources are sensitive to differences in climatic patterns. It is expected that there will be alterations on water resources sector because of climate change, which include runoff, floods, drought, snow melt and glacier melt, water quality and ground water. Variability in climate causes change of flooding patterns in space and time. During the twentieth century several studies inspected potential trends in measures of river discharge at different spatial scales, some detected significant trends in several indicators of flow, and some confirmed statistically significant links with tendencies of temperature or precipitation. In addition, human interferences have affected flow regimes in many catchments at the global scale, and there is evidence of a broadly coherent pattern of change in annual runoff, with some regions experiencing rise in runoff (Bates, Kundzewicz et al. 2008). Among many dangers of climate changes, Sea level rise is one of the well-known. When humanity contaminates the atmosphere with greenhouse smokes, the planet warms. When it ensures so, ice sheets and glaciers melt and warming sea water expands, increasing the volume of the world's oceans. The prices vary from nearby rises in shoreline flooding that can destruct infrastructure and harvests to the permanent dislocation of seaside societies (Lu and Flavelle 2019).

The additional heat because of global warming has enhanced the drying process in the current earlier , possible to cause more severe, insistent, and extensive droughts in the forthcoming by respect to the current climate. Moreover, rises in severity in drought of future climates could be largely produced by the despicable state alteration in the heating world (Javadinejad, Hannah et al. 2019). The consequences of weather alteration are two-fold – water availability and water quality. Increases in the demand in regions of scarcity can force the use of poor or unsuitable water with drastic repercussions for industry, human health and the associated costs of health care (Davraz, Sener et al. 2019).

2.1.2 Climate Change, Crop Production and Irrigation Requirement

Climate change is expected to have a significant impact on agricultural output (Asseng, Martre et al. 2019). As a major water user in the country and globally, the agricultural sector is expected to develop water management strategies that would minimize the impacts of water shortage on crop production. Increases in irrigation water requirements in most regions caused by crop demand growth due to socioeconomic development (Nechifor and Winning 2017).Therefore, the frequency of climate change will turn into more noticeable at time with increasing pressure on freshwater resources coming from crop production. This conjunction of socioeconomic and climatic drivers of freshwater use indicate the significance of seeing the implications of typical weather change on freshwater demand when analyzing the country of future water scarcity (Nechifor and Winning 2019). Some result reports expected water shortages due to increased water demands would result in a reduction in crop yields. The major challenge in understanding the links between cropping systems and climate change is the uncertainty of how the climate would change in the future and also the lack of understanding how different crops would respond to those changes. Therefore, in order for the irrigated agricultural sector to be sustainable across the country, farming practices and management strategies have to be modified based on site-specific information regarding the potential impacts of climate change on irrigation water requirements and water budget components of different crops (Matewos 2019).

2.1.3 Climate Models

The Earth's climate is governed by the interaction between many processes in the atmosphere, ocean, land surface and cryosphere (glaciers and ice sheets). Climate model are a mathematical demonstration of the weather system based on the physical, chemical, and biological properties of its constituents, their relations and response developments, and accounting in place of entirely or some of its recognized possessions. The climate system can be symbolized by models of variable intricacy, that is, for any one constituent or arrangement of constituents a range or order of models can be recognized, conflicting in such characteristics as the number of spatial measurements, the range to which physical, chemical, or biological processes are clearly characterized, or the level at which experimental parameterizations are included. Coupled Atmosphere-Ocean General Circulation Models (AOGCMs) provide a comprehensive representation of the climate system that is near or at the most comprehensive end of the spectrum currently available. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, and for operational purposes, including monthly, seasonal, and inter annual climate predictions (van Diemen 2019).

The current state of climate modeling science is accomplished with general circulation models (GCMs), which integrate complex interactions of atmosphere-land-ocean-ice systems that simulate the Earth's climate and projections of its future change on time scales of seasonal forecasts to decades and centuries.

Climate change scenarios developed from General Circulation Models (GCMs) are the initial source of information for estimating plausible future climate. Most GCMs have a plane resolution of between 250 and 600 km, and 10 to 20 perpendicular strata in the atmosphere (Thornes 2002). The spatial resolution of GCMs is too coarse to resolve regional scale effect therefore downscaling is required. In order to assess the implications of future changes in the environment, society and economy on primer unit, it is first necessary to have information about the present day or recent conditions as a reference point or baseline.

In order to characterize the present day climate in a region, good quality observed climatological data are required for a given baseline period. Issues to consider in selecting the climatological baseline include the types of data required, duration of the baseline period, sources of the data and how they can be applied in an impact assessment.

Almost all of hydrologists are aware of the World Meteorological Organization (WMO)-suggested 30-year time for "usual", which are used as base years beside which anomalies are calculated. Most, climate-linked data are referenced to 30-year periods. Currently the climatic regular normal time is 1981-2010. These climatic standard normal are reorganized every single ten years after we pass a new year finish in a zero. That is, the afterward period for climatic standard normal will be 1991-2020, so the move to new climatic regular normal will take place in a few years (Organization 2017). While generally the World Meteorological Organization prefers reference periods that span 30 years (e.g., 1971-2000, or 1981-2010), the IPCC-AR5 (Stocker, Qin et al. 2013) broadly utilized a 20-year interval of 1986-2005. This period covers the final 20 years of the historical simulations that were driven with observed radiative forcing's so, the analysis done in this paper done by dividing the century to four bench marks namely 2020-2039, 2040-2059, 2060-2079, and 2080-2099.

Baseline climatological data are found from a number of different sources that can be applied in impact assessments. The most common home for observed climatological data applied in impact assessments is the national meteorological agencies. These agencies usually have duty for the day-to-day operation and preservation of national meteorological observational networks for purposes of weather projecting and other public services.

The second one is international and worldwide data sets include observations of surface variables at a monthly time step over land and ocean, surface and upper air observations at a daily time step from sites across certain counties and for recent decades, satellite observations. Three, from stochastic weather generators a computer models that generate synthetic series of daily or sub-daily resolution weather at a site condition on the statistical features of the historically observed climate. The last one is finding the baseline climatological data from Climate model outputs of reanalysis data and outputs from GCM control simulations.

Reanalysis data are fine resolution gridded data which associate observations with simulated data from numerical models. Through a process known as data assimilation, the observations, along with data from satellites and information from the preceding model forecast, are input into a short-range weather forecast model. This is integrated forward by one time step and combined with observational data for the matching period. The result is a complete and dynamically reliable three-dimensional gridded data set which represents the best estimate of the state of the atmosphere at that time. The assimilation process blocks data voids with model forecasts and provides a set of constrained estimates of unobserved measures such as vertical motion and precipitation.

Outputs from GCM control simulations are model-based basis of information. The current climate is multi-century control replications from Atmospheric Ocean General circulation Models (AOGCMs). These simulations attempt to signify the dynamic forces of the global climate system unprompted by anthropogenic changes in atmospheric arrangement. Since explanations with a reasonable global coverage barely cover beyond one century in duration, model control simulations offer another source of data allowing impact analysts to examine the impact of multi-decadal deviations in climate.

2.1.3 Climate Scenario

Climate forecasts are normally offered for a variety of reasonable paths, scenarios, or marks that detain the interactions among human selections, discharges, concentrations, and temperature variation. Certain scenarios are reliable with sustained reliance on fossil fuels, whereas others can only be attained by careful activities to decrease emissions. The subsequent series reveals the anxiety nature in evaluating human actions and their effect on climate.

The first Intergovernmental Panel on Climate Change Assessment Report (IPCC FAR) on 1990 talk over three types of scenarios: equilibrium scenarios, in which CO_2 concentration was static; transient scenarios, in which CO_2 concentration enlarged by a stable proportion every year above the length of the scenario; and four brand-new Scientific Assessment (SA90) emission scenarios based on World Bank population projections. Nowadays, that new portfolio has prolonged to incorporate a wide range of time-dependent or transitory scenarios that project in what way people, energy sources, knowledge, emissions, atmospheric concentrations, radiates forcing, and/or universal temperature change over time (Hayhoe, Edmonds et al. 2017).

Climate change scenarios for impact assessment can be advanced in three major methods. Analogue scenarios are created by identifying a recorded climate regime which may look like the future climate predicted for a particular region. These recorded climates may be recognized in the long observational record at a site or be from other geographical locations. Synthetic scenarios are the greenest climate scenarios existing. They are used mainly for describing the sensitivity of an exposure unit to a plausible range of climatic variations, but they rarely present a future climate that is realistic and physically plausible. Synthetic scenarios refer to methods where particular climatic (or related) components are altered by a realistic but random amount, often according to a qualitative explanation of climate model replications for a region. For example, adjustments of baseline temperatures by +1, 2, 3 and 4°C and baseline precipitation by ±5, 10, 15 and 20 percent could represent various magnitudes of future change (Luo and Yu 2012).

Scenarios from general circulation model outputs are the most shared method of developing climate scenarios for quantifiable impact assessment. These are numerical models signifying physical processes in the atmosphere, ocean, cryosphere and terrestrial surface and considered as the most advanced tools presently available for simulating the reaction of the universal climate system to increasing greenhouse gas concentrations. GCMs show the climate using a three dimensional grid beyond the sphere, obviously taking a horizontal resolution of between 250 and 600 km, 10 to 20 perpendicular layers in the atmosphere and occasionally as many as 30 layers. Of the above methods, Scenarios from general circulation model yields were the most accurately specified and the most commonly used.

Irrespective of whether the climate changes in the future or not, there is no uncertainty that changes in socioeconomic and environmental conditions will happen. The major fundamental cause of rapid changes in atmospheric arrangement is human economic activity, in particular emissions of greenhouse gases and aerosols, and changing land cover and land use. Carbon dioxide is influential greenhouse gas and on last 150 years humanity's fossil fuel use has increased its atmospheric concentration from 280 ppm in the pre-industrialization era to nearly 405 ppm in 2016. However, not only CO_2 that governs the climate of our world eventually but also, it is both the power of the greenhouse effect and the entire received sunlight that is significant. Variations in either factor are able to force climate change.

Other scenarios are simply expressed in terms of an end-goal or target, such as capping cumulative carbon emissions at a specific level or stabilizing global temperature at or below a certain threshold such as 3.6°F (2°C), a goal that is often cited in a range of scientific and policy discussions, most recently the Paris Agreement (Obergassel, Arens et al. 2015).To alleviate climate at any specific temperature level, though, it is not sufficient to stop the growth in yearly carbon emissions. Universal net carbon emissions will in the long run need to reach zero and negative emissions may be needed for a greater-than-50% chance of regulating heating below 3.6°F(Collins, Knutti et al. 2014).

Scenarios

The climate modeling community used time-dependent scenarios which are standard, as input to global climate model simulations and deliver the foundation for the majority of the forthcoming projections offered in IPCC assessment reports and U.S. National Climate Assessments (NCAs). Established by the integrated assessment modeling community, these groups of standard scenarios have develop more comprehensive with each new generation, as the original SA90 scenarios *(Houghton, Jenkins et al. 1990)* were replaced by the IS92 emission scenarios of the 1990s, (Leggett, Pepper et al. 1992) which were in turn prospered by the Special Report on Emissions Scenarios in 2000 (SRES) (Nakicenovic, Alcamo et al. 2000) and by the Representative Concentration Pathways in 2010 (RCPs) (Moss, Edmonds et al. 2010).

SA90, IS92, and SRES are all emission-based scenarios. They begin with a set of plots that were based on population forecasts initially. By SRES, they had become much more merged, laying out a reliable picture of demographics, international trade, flow of information and technology, and other social, technological, and economic structures of future worlds. These agreements were then fed through socioeconomic and Integrated Assessment Models (IAMs) to derive emissions. For SRES, the use of various IAMs resulted in multiple emissions scenarios corresponding to each storyline. However, one scenario for each storyline was selected as the representative scenario to be used as input to global models to calculate the resulting atmospheric concentrations, radiative forcing, and climate change for the higher A1fi (fossil-intensive), mid-high A2, mid-low B2, and lower B1 storylines. IS92-based projections were used in the IPCC Second and Third Assessment Reports (SAR and TAR) (Stouffer, T TOKIOKA et al. 1996), the first NCA (NAST, 2001) Projections based on SRES scenarios were used in the second and third NCAs, (Melillo, Richmond et al. 2014)) as well as the IPCC TAR and Fourth Assessment Reports (AR4) (Meehl, Stocker et al. 2007).

The most recent set of time-dependent scenarios, RCPs, builds on these two decades of scenario development. However, RCPs differ from previous sets of standard scenarios in at least four important ways. First, RCPs are not emissions scenarios; they are radiative forcing scenarios. Each scenario is tied to one value: the change in radiative forcing at the tropopause by 2100 relative to preindustrial levels. The four RCPs are numbered according to the change in radiative forcing by 2100: +2.6, +4.5, +6.0 and +8.5 watts per square meter (W/m2).(Van Vuuren, Stehfest et al. 2011), (Thomson, Calvin et al. 2011), (Riahi, Rao et al. 2011).

The second difference is that, starting from these radiative forcing values, IAMs are used to work backwards to derive a range of emissions trajectories and corresponding policies and technological strategies for each RCP that would achieve the same ultimate impact on radiative forcing. From the multiple emissions pathways that could lead to the same 2100 radiative forcing value, an associated pathway of annual carbon dioxide and other anthropogenic emissions of greenhouse gases, aerosols, air pollutants, and other short-lived species has been selected for each RCP to use as input to future climate model simulations (Lamarque, Kyle et al. 2011), (Stocker, Qin et al. 2013). In addition, RCPs provide climate modelers with gridded trajectories of land use and land cover.

A third difference between the RCPs and previous scenarios is that while none of the SRES scenarios included a scenario with explicit policies and measures to limit climate forcing, all of the three lower RCP scenarios (2.6, 4.5, and 6.0) are climate-policy scenarios. At the higher end of the range, the RCP8.5 scenario corresponds to a future where carbon dioxide and methane emissions continue to rise as a result of fossil fuel use, albeit with significant declines in emission growth rates over the second half of the century , significant reduction in aerosols, and modest improvements in energy intensity and technology (Lamarque, Kyle et al. 2011). Atmospheric carbon dioxide levels for RCP8.5 are similar to those of the SRES A1FI scenario: they rise from current-day levels of 400 up to 936 ppm by the end of this century. CO2-equivalent levels reach more than 1200 ppm by 2100, and global temperature is projected to increase by 5.4°–9.9°F (3°–5.5°C) by 2100 relative to the 1986–2005 average. RCP8.5 reflects the upper range of the open literature on emissions, but is not intended to serve as an upper limit on possible emissions nor as a business-as-usual or reference scenario for the other three scenarios.

Under the lower scenarios (RCP4.5 and RCP2.6), (Van Vuuren, Stehfest et al. 2011) (Thomson, Calvin et al. 2011), atmospheric CO2 levels remain below 550 and 450 ppm by 2100, respectively. Emissions of other substances are also lower; by 2100, CO2-equivalent concentrations that include all emissions from human activities reach 580 ppm under RCP4.5 and 425 ppm under RCP2.6. RCP4.5 is similar to SRES B1, but the RCP2.6 scenario is much lower than any SRES scenario because it includes the option of using policies to achieve net negative carbon dioxide Emissions before the end of the century, while SRES scenarios do not. RCP-based projections were used in the most recent IPCC Fifth Assessment Report (AR5) (Flato, Marotzke et al. 2014) and (Melillo, Richmond et al. 2014).

Within the RCP family, separate scenarios have not been allocated a formal likelihood. Higher-amount scenarios parallel to higher emissions and a larger and quick global temperature change; the range of values covered by the scenarios was chosen to reflect the then-current range in the open literature. Since the choice of scenario restraints the levels of future changes, most assessments quantify future change and parallel impacts under a range of future scenarios that reflect the uncertainty in the significances of human choices over the coming century.

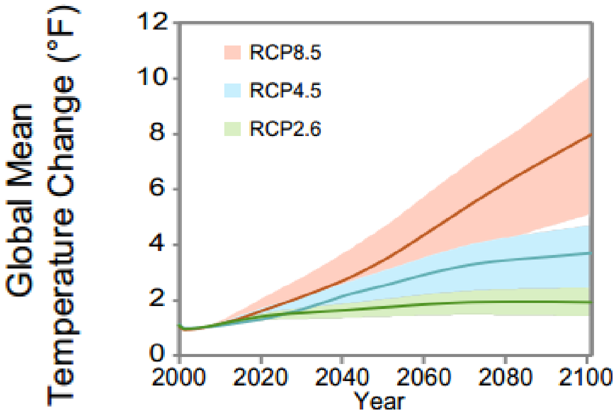


Figure 1: change in Temp for different Rcp for 2000-2100

2.2 Modeling Tools

Using transient setups such as SRES and RCP as input, global climate models (GCMs) produce trajectories of future climate change, including global and regional changes in temperature, precipitation, and other physical characteristics of the climate system (Collins, Knutti et al. 2014), (Kirtman, Power et al. 2013) Power, The resolution of global models has increased significantly since IPCC FAR.19 However, even the latest experimental high-resolution simulations, at 15–30 miles (25–50 km) per grid box, are unable to simulate all of the important fine-scale processes occurring at regional to local scales. Instead, downscaling approaches often used to accurate systematic biases, or offsets relative to observations, in global projections and translate them into the higher-resolution information typically required for impact assessments.

Dynamical downscaling with regional climate models (RCMs) directly simulates the response of regional climate processes to global change, while empirical statistical downscaling models (ESDMs) incline to be more flexible and computationally efficient. Comparing the ability of dynamical and statistical methods to replicate observed climate indicate that the relative performance of the two approaches depends on the assessment criteria (Ayar, Vrac et al. 2016). Although dynamical and statistical methods can be combined into hybrid structure, many assessments still tend to depend on one or the other type of downscaling, where the choice is based in the requirements of the assessment.

2.2.1 Global Climate Model

Global climate models are mathematical structures that were first built on vital equations of physics. They account for the conservation of energy, mass, and momentum and how these are switch over among different constituents of the climate system. Using these fundamental relationships, many important aspects of Earth's climate: large-scale patterns of temperature and precipitation, general characteristics of storm tracks and extratropical cyclones, and observed changes in global mean temperature and ocean heat content as a result of human emissions are simulated by GCMs (Flato, Marotzke et al. 2014).

The complication of climate models has grown over time, as they include additional components of Earth's climate system. Global climate models simulate additional structures of the climate system: atmospheric chemistry and aerosols, land surface interaction by soil and vegetation, land and sea ice.

In addition to increasing the number of processes in the models and refining the treatment of existing processes, the total number of GCMs and the average horizontal spatial resolution of the models have increased over time, as computers become more powerful, and with each successive version of the World Climate Research Program's (WCRP's) and Coupled Model Inter comparison Project (CMIP). CMIP5 offers output from over 50 GCMs with spatial resolutions going from about 30 to 200 miles per horizontal size and flexible vertical resolution on the order of hundreds of meters in the lower atmosphere.

2.2.2 Regional Climate Models

Dynamical downscaling models are often mentioned as regional climate models, since they include same physical processes that make up a global climate model, but simulate these processes at higher spatial resolution over smaller regions (Kotamarthi, Mearns et al. 2016).Most RCM simulations use GCM fields from pre-computed global simulations as periphery conditions. This approach allows RCMs to draw from a broad set of GCM simulations, such as CMIP5, but does not allow for possible two-way reactions and relations between the regional and global scales. Dynamical downscaling can also be presented interactively over nesting a higher-resolution regional grid or model into a global model in the course of simulation. Both methods directly simulate the dynamics of the regional climate system, but only the second allows for two-way connections between regional and global change.

RCMs are computationally concentrated, providing a broad range of output variables that resolve regional climate features important for assessing climate impacts. The size of single grid cells can be as fine as 1 to 2 km per grid box in some studies, but more commonly range from about 10 to 50 km. At smaller spatial scales, and for specific variables and areas with complex terrain, such as coastlines or mountains, regional climate models have been shown to add value (Feser, Rockel et al. 2011) . As model resolution increases, RCMs are also able to explicitly resolve some processes that are parameterized in global models. For example, some models with spatial scales below 4 km are able to dispense with the parameterization of convective precipitation, a significant source of error and uncertainty in coarser models (Prein, Langhans et al. 2015). RCMs can also intersection changes in land use, land cover, or hydrology into resident climate at spatial scales significant to planning and decision-making at the county level.

2.2.3 Empirical Statistical Downscaling Models

Empirical statistical downscaling models (ESDMs) association GCM output with historical observations to translate large-scale patterns into high-resolution projections at the scale of observations. The observations used in an ESDM can range from single weather stations to gridded datasets. As output, ESDMs can produce a range of products, from large grids to examine optimized for a specific location, variable, or decision-context.

Statistical techniques are varied, from the simple difference or delta approaches (subtracting historical simulated values from future values, and adding the resulting delta to historical observations) (Meehl, Stocker et al. 2007) to the parametric quintile mapping approach (Stoner, Hayhoe et al. 2013), Even more complex clustering and advanced mathematical modeling techniques can rival dynamical downscaling in their demand for computational resources (Vrac, Stein et al. 2007).

Statistical models are mostly flexible and less computationally difficult than RCMs. A number of databases using a variety of methods, including the LOcalized Constructed Analogs method (LOCA), offer statistically downscaled projections for continual period from 1960 to 2100 using a large group of global models and a range of higher and lower future scenarios to capture uncertainty due to human activities. ESDMs are also effective at eliminating biases in historical simulated values, leading to a good match between the average statistics of observed and statistically downscaled climate at the spatial scale and over the historical period of the observational data used to sleeper the statistical model. Unless methods can concurrently downscale multiple variables, however, statistical downscaling carries the risk of changing some of the physical interdependences between variables. ESDMs are also limited in that they require observational data as input; the longer and more complete the record, the greater the confidence that the ESDM is being trained on a representative sample of climatic conditions for that location (Hayhoe, Edmonds et al. 2017).

2.3 Decision Support Models and Selection Criteria's

DSS are software-based systems that fold and analyses data from a range of sources. Their purpose is to smooth the decision-making process for management, operations, planning, or optimal solution path recommendation. In the agricultural sector, it helps farmers to resolve complex issues related to crop production. As tools for diagnosis, risk assessment and reasoning assistance, DSS use agronomic models and calculations based on water, climate, energy and genetic data but they also take into account other factors such as human and economic inputs (Kukar, Vračar et al. 2019).

Crop simulation models

Crop simulation models (CSM) or crop models are computerized representations of crop growth, development, and yield, simulated through mathematical equations as a function of soil conditions, weather, and management options (Basso, Cammarano et al. 2013) .

Crop models have been developed to simulate risks associated with crop management options in the face of climatic change and variability. They simulate plant growth, development, and yield in response to water, temperature, solar radiation and nutrient inputs. They describe crop growth, development and yield at field scale on a daily time stamp and require site-specific, spatially homogeneous weather data as input (Zare, Fallah et al. 2016). Crop models assist in understanding the relationship between weather, climate and crop yield (Vučetić 2006). They are used in impact and climate change and variability studies, as they account for plant eco-physiological processes, environmental and management options for different cultivars and locations (Bassu, Brisson et al. 2014).

Field forecasting can be carried out using crop models to give the yield of a precise and scientific crop as early as possible during the crops' growing season by considering the effect of the weather and climate (Basso, Cammarano et al. 2013). Crop models can be used to evaluate the site-specific impact of climate change, agro-technologies and to accurately predict crop yield with prior knowledge of the soil properties and crop management practices or options. Crop models have been applied in approximating yield potential in crop ideotypes designed for simulated future climate scenarios (Asseng, Martre et al. 2019). Crop simulation models have been used to describe systems and processes at genotype level, crop, farming system, region, and global environment. However, the extent to which crop models in developing countries have benefited the poor is limited. Crop models offer opportunities for exploring cultivar potential in areas not explored before, establishing expensive and laborious field trials (Kihara, Martius et al. 2012). Lengthy and costly agronomic and modeling field trials with a high number of treatments, could be pre-evaluated by conducting, in minutes, experiments on a desktop computer or laptop (Steduto, Raes et al. 2009). Crop simulation modeling can be used to decide on the optimum plant densities and dates of planting for maize crop (Chisanga, Phiri et al. 2015).

In recent times, several studies around the globe indicate that climatic changes are likely to impact the food production and poses serious challenge to food security. Most prominently, human-caused climate change will influence the quality and quantity of food we produce and our ability to distribute it equitably. Our capacity to ensure food security and nutritional adequacy in the face of rapidly changing biophysical conditions will be a major determinant of the next century's global burden of disease (Myers, Smith et al. 2017).

In the face of climate change, agricultural systems need to adapt measures for not only increasing food supply catering to the growing population worldwide with changing dietary patterns but also to negate the negative environmental impacts on the earth. Crop simulation models are the primary tools available to assess the potential consequences of climate change on crop production and informative adaptive strategies in agriculture risk management. In consideration with the important issue, this is an attempt to provide a review on the relationship between climate change impacts and crop production. It also emphasizes the role of crop simulation models in achieving food security. Significant progress has been made in understanding the potential consequences of environment-related temperature and precipitation effect on agricultural production during the last half century. Increased CO2 fertilization has enhanced the potential impacts of climate change, but its feasibility is still in doubt and debates among researchers. To assess the potential consequences of climate change on agriculture, different crop simulation models have been developed, to provide informative strategies to avoid risks and understand the physical and biological processes. Furthermore, they can help in crop improvement programs by identifying appropriate future crop management practices and recognizing the traits having the greatest impact on yield (Kumar 2016).

The use of these models can be summarized as:

(i) better understanding of water-food-climate change interactions, and

(ii) exploring options to improve agricultural production now and under future climates.

Some of the frequently applied agricultural models are:

- CROPWAT
- AQUACROP

- CROPSYST
- SWAP/WOFOST
- CERES
- DSSAT
- EPIC

Each of these models is able to simulate crop growth for a range of crops. The main differences between these models are the representation of physical processes and the main focus of the model. Some of the models mentioned are tough in analyzing impact of fertilizer use, the ability to simulate different crop varieties, farmer practices, etc. However, for the project it is required to use models with a strong emphasis on crop-water-climate interactions. The three models that are specifically strong on the relationship between water availability, crop growth and climate change are CropWat, AquaCrop and SWAP/WOFOST (Kasampalis, Alexandridis et al. 2018)). Moreover, these three models are in the public domain, have been applied world-wide frequently, and have a user friendly interface.

AquaCropis selected as it has;

- limited data requirements,
- a user-friendly interface enabling non-specialist to develop scenarios,
- focus on climate change, CO2, water and crop yields,
- developed and supported by FAO,
- fast growing group of users world-wide,
- flexibility in expanding level of detail

2.4 AquaCrop Model

AquaCrop is the FAO crop-model to simulate yield response to water. It is designed to balance simplicity, accuracy and robustness, and is particularly suited to address conditions where water is a key limiting factor in crop production. AquaCrop is a companion tool for a wide range of users and applications including yield prediction under climate change scenarios. AquaCrop is a completely revised version of the successful CropWat model. The main difference between CropWat and AquaCrop is that the latter includes more advanced crop growth routines (MacCarthy, Kihara et al. 2018)

To develop recommendation to improve water efficiency we can run field experiment and it will take many years before valid recommendation because it require different weather conditions, different crops and different management. So instead of field assessment we can run simulation with model. Simulation is performed by means of mathematical model. Mathematical models are simplified representation of a particular system. In Aquacrop the main interest is the field where the plants are cultivated. The plant production depend highly on the soil condition so there will be an interaction between the plant and the soil. The plant will grow if there is enough water on the soil and if the soil is poorly fertilized and dry there is no plant development. This interaction is the system which is modeled. The system (the interaction between plant and soil) also affected by management which (field and irrigation) which is fertility, when and in what amount to apply irrigation water. The system link with the outside world which is upper boundary. At upper boundary there is weather condition which describe what is the rain fall, how many energy's available to vaporize water and what is the concentration of carbon dioxide .At lower boundary ground water table is linked to the system in which water from the system drain and the water table close to the soil and subsoil then water move by capillary rise from the water table to the sub soil. Water table is not concern of Aquacrop but it intrusion in water quality of soil water is considered here (Vanuytrecht, Hsiao et al. 2014) .

2.4.1 Model Specifications

AquaCrop includes the following sub-model components: the soil, with its water balance; the crop, with its development, growth and yield; the atmosphere, with its thermal regime, rainfall, evaporative demand and CO2 concentration; and the management, with its major agronomic practice such as irrigation and fertilization.

The particular features that distinguishes AquaCrop from other crop models is its focus on water, the use of ground canopy cover instead of leaf area index, and the use of water productivity values normalized for atmospheric evaporative demand and of carbon dioxide concentration. This enables the model with the extrapolation capacity to diverse locations and seasons, including future climate scenarios. Moreover, although the model is simple, it gives particular attention to the fundamental processes involved in crop productivity and in the responses to water, from a physiological and agronomic background perspective.

2.3.2 Theoretical Assumptions

The complexity of crop responses to water deficits led to the use of empirical production functions as the most practical option to assess crop yield response to water. Among the empirical function approaches, FAO Irrigation & Drainage Paper nr 33 (Doorenbos and Kassam 1979) represented an important source to determine the yield response to water of field, vegetable and tree crops, through the following equation:

$$\frac{Yx - Ya}{Yx} = \frac{ky(ETx - ETa)}{ETx}$$

WhereYx and Ya are the maximum and actual yield, ETx and ETa are the maximum and actual evapotranspiration, and ky is the proportionality factor between relative yield loss and relative reduction in evapotranspiration (Vanuytrecht, Raes et al. 2014).

The main components included in AquaCrop to calculate crop growth are (Mibulo and Kiggundu 2018):

- Atmosphere

- Crop
- Soil
- Field management
- Irrigation management

2.3.3 Atmosphere

The minimum weather data requirements of AquaCrop include the following five parameters:

- daily minimum air temperatures
- daily maximum air temperatures
- daily rainfall
- daily evaporative demand of the atmosphere expressed as reference evapo-transpiration (ETo)
- mean annual carbon dioxide concentration in the bulk atmosphere

The reference evapotranspiration (ETo) is, in contrast to CropWat, not calculated by AquaCrop itself, but is a required input parameter. This enables the user to apply whatever ETo method based on common practice in a certain region and/or availability of data. From the various options to calculate ETo reference is made to the Penman-Monteith method as described by FAO (Vanuytrecht, Hsiao et al. 2014). The same publication makes also reference to the Hargreaves method in case of data shortage.

A few additional parameters were used for a more reliable estimate of the reference evapotranspiration. Besides the minimum and maximum temperature, measured dewpoint temperature and windspeed were used for the calculation.

AquaCrop calculations are performed always at a daily time-step. However, input is not required at a daily time-step, but can also be provided at 10-daily or monthly intervals. The model itself interpolates these data to daily time steps. The only exception is the CO2 levels which should be provided at annual time-step and are considered to be constant during the year.

2.3.4 Crop

AquaCrop considers five major components and associated dynamic responses which are used to simulate crop growth and yield development:

- phenology
- aerial canopy
- rooting depth
- biomass production
- harvestable yield

As mentioned earlier, AquaCrop strengths are on the crop responses to water stress. If water is limiting this will have an impact on the following three crop growth processes:

- reduction of the canopy expansion rate (typically during initial growth)
- acceleration of senescence (typically during completed and late growth)
- closure of stomata (typically during completed growth

Finally, the model has two options for crop growth and development processes:

- calendar based: the user has to specify planting/sowing data
- thermal based on Growing Degree Days (GDD): the model determines when planting sowing starts

2.3.5 Soil

AquaCrop is flexible in terms of description of the soil system. Special features:

- Up to five horizons
- Hydraulic characteristics:
  - conductivity at saturation
  - volumetric water content at saturation
  - field capacity
  - wilting point
- Soil fertility can be defined as additional stress on crop growth influenced by:

- water productivity parameter
- the canopy growth development
- maximum canopy cover
- rate of decline in green canopy during senescence.

AquaCrop separates soil evaporation (E) from crop transpiration (Tr). The simulation of Tr is based on:

- Reference evapotranspiration
- Soil moisture content
- Rooting depth

Simulation of soil evaporation depends on:

- Reference evapotranspiration
- Soil moisture content
- Mulching
- Canopy cover
- Partial wetting by localized irrigation
- Shading of the ground by the canopy

2.3.6 Field Management

Characteristics of general field management can be specified and are reflecting two groups of field management aspects: soil fertility levels and practices that affect the soil water balance. In terms of fertility levels one can select from pre-defined levels (non-limiting), near optimal, moderate and poor) or specify parameters obtained from calibration. Field management options influencing the soil water balance that can be specified in AquaCrop are mulching, runoff reduction and soil bunds

2.3.7 Irrigation Management

Simulation of irrigation management is one of the strengths of AquaCrop with the following options:

- Rain fed-agriculture (no irrigation)
- sprinkler irrigation
- drip irrigation
- surface irrigation by basin
- surface irrigation by border
- surface irrigation by furrow

Scheduling of irrigation can be simulated as

- Fixed timing
- Depletion of soil water

Irrigation application amount can be defined as:

- Fixed depth
- Back to field capacity

2.3.8 Climate Change

The impact of climate change can be included in AquaCrop by three factors:

(i) adjusting theprecipitation data file,
(ii) adjusting the temperature data file,
(iii) impact of enhanced CO2 levels

The first two options are quite straightforward and require the standard procedure of creating climate input files in AquaCrop. Impact of enhanced CO2 levels is calculated by AquaCrop itself. AquaCrop uses for this the so-called normalized water productivity (WP*) for the simulation of aboveground biomass. The WP is normalized for the atmospheric CO2 concentration and for the climate, taking into consideration the type of crop (e.g. C3 or C4). The C4 crops assimilate carbon at twice the rate of C3 crops (Steduto, Raes et al. 2009).

2.4 Review of Previous Studies

There are limited climate change impact studies in Awash River basin. Some of the previous research results are shown below.

(Taye, Dyer et al. 2018) study presents the most probable projections for the impact of climate change on the Awash basin hydro-climatic variables, using a methodological approach based on selecting best performing GCMs followed by a change factor method that accounted for sampling uncertainty due to the choice of periods. According to the result, hydro-climatological variability is one of the main challenges facing the Awash basin's water resources management. The study has shown that climate change will have major implications for water availability in this basin. Based on selected climate models that best captured the historical characteristics of the basin's climate, intensified water stress is projected for three future periods. This is due to an increase in temperature and subsequent intensification of evapotranspiration which is consistent across the climate models. Decreasing precipitation in the April–June months is a major concern for the irrigation sector and for the basin authority on water allocation among various users.

(Gedefaw, Hao et al. 2019) for this study WEAP model is used for formulated the water allocation networks under climate change and irrigation expansion to the Awash River Basin. The study also calibrated and validated the stream flow effectively with a rational range of R^2 and NSE. The annual water balance for Awash basin was also determined by allowing the main constraints that could affect the water availability of the basin. Population growth, expansion, industrialization, and agricultural increase further magnify the conflicts of water between users. Reasonable allocation of water among conflicting sites and sighting another possibility to improve the water availability of the basin must be given attention. Water collecting, soil, and water conservation to minimize the rate of runoff and digging boreholes are some options to improve the water capacity of the basin.

(Adeba, Kansal et al. 2015), study developed a surface water balance for Awash basin using SWAT model. Based on the study, the annual water balance for Awash river basin was evaluated taking into account all the parameters that could be evaluated. The water balance calculation for the basin revealed that the basin is water deficit. The total surface water yield of the basin is estimated to be 4.64 BCM, while the total demand is about 4.67 BCM. This shows that there is a deficit of 0.03 BCM/year of surface water in the basin. The seasonal water deficit is even very serious. The monthly deficit and surplus of water is calculated for the last 2 years of the study period. During December to April month of the year 2011, the basin shows a deficit of 1.27 BCM, while there is an excess water of 1.67 BCM during the months of May to September. In 2012, during the similar months, there is a deficit of 2.82 BCM, whereas there is a surplus of 3.16 BCM of water during June–October.

The study of, (Murendo, Keil et al. 2011) show that in Awash River Basin severe drought periods have led to a significant depression of crop yields and to widespread death of livestock in the past. Drought periods have drastically increased the proportion of food insecure households and lengthened the duration of food insecurity in the area. Since, with climate change, drought periods are predicted to become more frequent in this region in the future, the problem of food insecurity is likely to become even more severe.

3. STUDY AREA AND DATA AVAILABILITY

3.1 Study Area Description

3.1.1 Location

Wonji–Shoa Sugar Estate lies downstream of the Koka Dam in the Central Rift Valley of Ethiopia in the Awash River Basin, 110 km southeast of Addis Ababa and 10 km south of Nazareth by road approximately between 8°21’ to 8°29’ N 39°12’ to 39°18’ E (figure 2, *(Degefa and Saito 2017)*. The estate (including out growers) has a total area of about 8000 ha (excluding the current under expansion) and the factory has a total crushing capacity of 3500 TCD (ton of cane). Approximately 9319 households (6184 male-headed and 3135 female-headed) participate in the out-grower scheme. Each household possesses between 0.2 and 6 ha of land (Wendimu, Henningsen et al. 2016) and the out-growers supply 60% of the total sugarcane crushed per year. The estate proper has about 6,100 ha of cultivated land and the remaining parts are occupied by residential area, factory, roads, canals and storage reservoirs. The estate proper is divided into nine management sections, each has its own section managers. The Water source is Awash River with diversion type of Pumping station. Major crop is Sugarcane, minor Haricot bean and Crotalaria (Dinka 2019).

From early large scale irrigation schemes, WSSE is one of the key in the Awash River Basin. Its launch in the basin marked the first era of large-scale irrigation progress and era of local sugar production in the Ethiopian history. Conferring to the witness from native people and others, the first modern and viable large-scale irrigation system in Ethiopia was started at Wonji plain at the end of 1930 by Italians to grow sugarcane, in the course of their second invasion of the country. This is marked from the Italian naming accepted up to date in WSSE (e.g., ‘Mallang’ for furrow, ‘Italian Canals’, etc) (Dinka 2019). Sugarcane is the most leading crop grown in the plantation, with few crotalaria and haricot bean on heavy black clay soil for the period of fallow period in the case of cane after fallow (CAF) system.

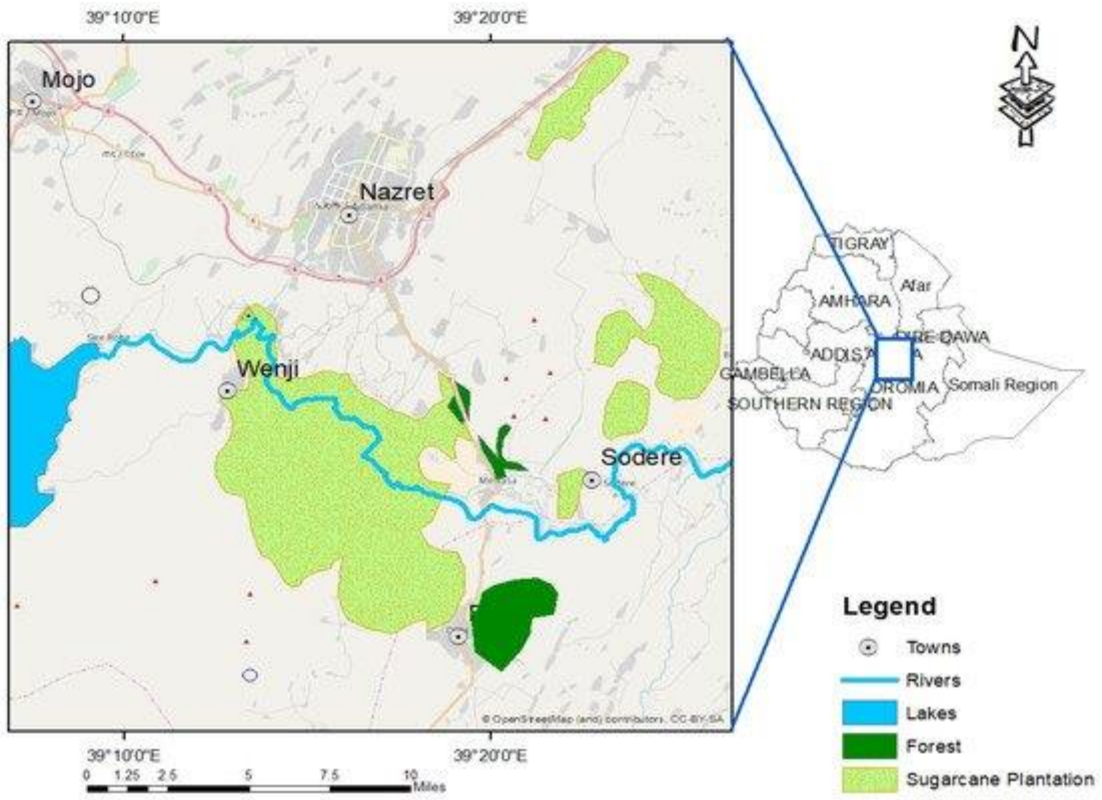


Figure 2: Map of the study area.

Italians worn out most of the Wonji swampland area in 1938 and then built long canals (at this time named 'Italian canals') and proceeding to growing sugarcane. Though certain group of people strained to continue using the farm after the removal of Italians from the country (1941), due to their collapse in the World War-II, they were ineffective and the farm was abandoned in 1946. In 1948, the Dutch Company named H.V. Amsterdam came to the area and begin farming based on the agreement made with Hailasillasse-I regime by relocating the local indigenous people, Karayyuu (one of the semi-pastoralist Oromo ethnic group named Jillle) living in the Awash Basin. Wonji Factory was initiated and started manufacturing the first bags of Ethiopian sugar in 1954 (March 20) (Dinka, Loiskandl et al. 2013).

3.1.2 Topography

The Wonji-Shoa Irrigation Scheme is found at an altitude of approximately 1,500 meters above sea level (m.a.s.l.). In the estate, generally, the slope of the farm is very gentle and regular.

3.1.3 Climate

WSSE has a semi-arid climate and obtains an average annual rainfall of 831.2 mm, highest daily evapotranspiration of 4.5 mm, mean annual maximum and minimum temperatures of 27.6°C and 15.2°C, respectively. The soil of WSSE are mainly Andosols, Fluvisols, Leptosols, and Phaeozemes, according to the FAO soil classification.The long term mean annual rainfall of WonjiShoa plantation is shown in Figure 2.

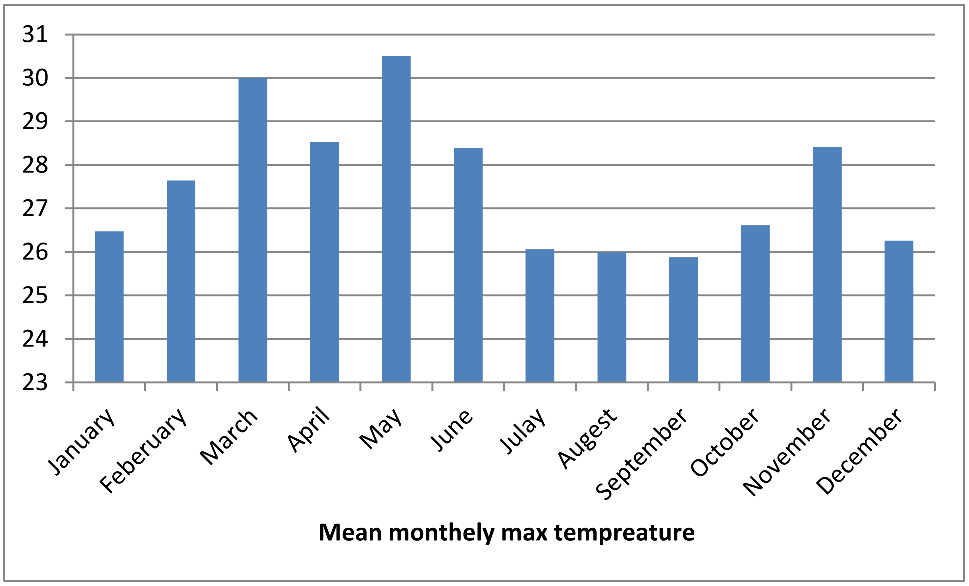


Figure 3: Mean monthly maximum temperature (1990-2016)

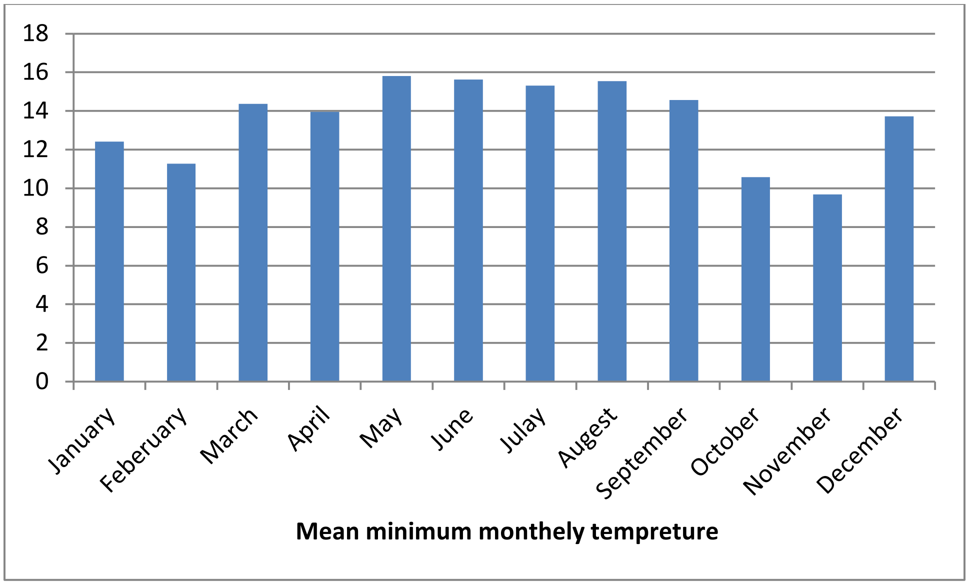


Figure 4: Mean monthly minimum temperature (1990-2016)

3.1.4 Land Cover and Land Use

The main forms of land cover use in the Wonjishoa irrigated land is perennial crop cover dominated by sugar cane plantation and uses high amount of water from Awash River during dry season of the year.

3.2 Data Availability

3.2.1 Meteorological Data

Meteorological data was required since it will used as input to the Aqua crop model in base line scenario. The metrological data obtained will be modeled in current carbon di oxide emission by Aquacrop of its yield production and irrigation management which used latter for compering the result with future scenario of different emission. The future metrological records which are already downscaled are available in different climate portal and used with bias correction. Based on these objectives, the meteorological data required for this study were collected from the Wonji Shoa sugarcane estate research center weather station, Ethiopian National Meteorological Services Agency (NMSA) at Addis Ababa. The daily meteorological data collected were precipitation, maximum and minimum temperature, relative humidity, wind speed and sunshine hours.

3.2.2 Crop, Irrigation and Soil Data

The crop, irrigation and soil data are used in Aqua crop model for simulation of the system (wonjishoa plantation state). The soils of WSSE are of alluvial-coluvial origin established under hot, tropical environments. Texturally, the soil can be categorized into light (course textured) and heavy (clayey black) soils. The heavy clay soils (≈70%) are the governing soil group in the plantation and characterized by natural problems such as compaction, poor structure, shallow GWTD, etc. As a result, soils like these are regarded as problematical by plantation's agricultural managers. The soils of Wonji-Shoa have been labeled predominantly as a complex of gray, cracking clays in the topographic depressions and semiarid, brown soils. The geology of Wonji plain is defined by volcanic actions and rift tectonics, which is characteristics of the Main Ethiopian Rift (MER) (Dechasa 1999). A network of irrigation (≈280 km) and drainage (≈203 km) canals are used in the area.

The estate sidetracked irrigation water from Awash River using centrifugal pumps and then to masonry lined main canal. There are seven main and twelve tertiary night storage reservoirs spread across the estate for accumulation of water during the continuous pump operation in the night time. Field water application is through block-ended furrow irrigation system and the excess water from the plantation fields are worn out through the network of surface drains. The network of irrigation system contains primary canals (480 m), secondary canals (≈76 km) and tertiary canals (≈203 km). There are also small canal arrangements (distribution tanks, flow divisors, road crossings, turnouts, canal falls, regulating, measuring etc) (Kedir and Engineer 2015).

The main crops cultivated are sugarcane, haricot bean and crotalaria. Sugarcane is planted at a rate of 16-18 t/ha in the estate and it is cultivated as perennial mono crop (Genanu, Alamirew et al. 2017).

3.2.3 Future Climate Scenario Data

The climate scenario data used here are freely available data which is already down scaled and can be used directly by bias correcting for model output of Cordex of four scenarios rcp2.5,rcp4.5, rcp6.5 and rcp8.5 produced by greenhouse gas, sulphate aerosol, and solar forcing and NCEP reanalysis data. The considered climate data are for medium and high (4.5rcp and8.5 rcp) scenarios of precipitation, maximum temperature and minimum temperature.

4. METHODLGY

Investigation of climate change impact in irrigation consists of the following steps:

1. Using Coordinated Regional climate Downscaling Experiment over African domain (CORDEX-Africa) with Coupled Model Inter-comparison Project Phase 5 (CMIP5) simulations under Representative Concentration Pathway‟s (under the effect of increasing greenhouse gases) for wonji shoa plantation estate compatible with Aquacrop model and,
2. Use of Aquacrop model to simulate the effects of climate change on small scale irrigation.

4.1 COORDINATED REGIONAL DOWNSCALING EXPERIMENT (CORDEX)

Coupled Atmosphere–Ocean General Circulation Models (GCMs) used for studding current and future climate globally, which simulate the climate of the Earth at spatial determination of a few hundred kilometers. To detained the local impacts of topography and land surface features on climate and provide a better explanation of extreme events, limited-area regional climate models (RCMs) are used to downscale GCM amount produced (Giorgi and Mearns 1999). This is prepared by nesting the RCM into the GCM, i.e., productions of the GCM are activated as boundary conditions for RCM simulations in a limited domain. The Coordinated Regional Climate Downscaling Experiment (CORDEX) (Giorgi and Mearns 1999) is an initiative funded by the World Climate Research Program. The goal is to scheme a set of standardized research intended at scale back GCM predictions from the Coupled Model Inter comparison Project phase 5 (CMIP5) (Taylor, Stouffer et al. 2012) in the widely held of the land areas of the world, both via RCMs and statistical techniques (dynamical and statistical downscaling, respectively). The trials based on dynamical downscaling contain imitations of an ensemble of RCMs of the current climate with forcing provided by both reanalysis produces and GCMs, and of future climate with GCM forcings under different Representative Concentration Pathways (Lamarque, Kyle et al. 2011). Specifically, the simulations of the current climate are performed in two experiments: (i) the "Evaluation" experiment (EVAL hereafter), where RCMs are driven by the European Centre for Medium-Range Weather Forecasts Interim Re-Analysis (ERAInterim; ERAINT) (Dee, Uppala et al. 2011) for a hindcast simulation of the 1989–2008 climate and (ii) the "Historical" experiment (HIST), where RCMs are driven by GCMs used in CMIP5 to simulate the 1950–2005 climate

CORDEX-Africa RCMs generate an ensemble of high resolution historical and future climate projections at regional scale by downscaling different GCMs forced by RCPs based on the Coupled Inter comparison Project Phase 5 (CMIP5). The African region was selected as the first target domain of the CORDEX experiments (CORDEX-Africa) for the reason that its susceptibility to climate change and the critical role of climate variability on agriculture, water managing, and health (Giorgi, Jones et al. 2008). A number of studies have examined the trustworthiness of the CORDEX simulations of the EVAL experiment. (Nikulin, Jones et al. 2012) assessed the climatology of precipitation of an ensemble of 10 RCM simulations in the entire continent, discover that all models simulate the seasonal mean and annual cycle accurately, with the exclusion of individual models in some regions. (Kim, Waliser et al. 2014) further estimated the same ensemble of RCMs viewing that the models have higher skills in simulation of precipitation and temperature in the western rather than the eastern part of Africa. (Gbobaniyi, Sarr et al. 2014) accompanied a parallel analysis with focus on West Africa and established that RCMs rationally put on the existence and movement of the West African monsoon but that some of them exhibit biases of different extent that vary with model and location. was selected as the first target domain of the CORDEX experiments (CORDEX-Africa) because of its vulnerability to climate change and the critical role of climate variability on agriculture, water management, and health (Giorgi, Jones et al. 2008). A number of studies have investigated the reliability of the CORDEX simulations of the EVAL experiment. (Nikulin, Jones et al. 2012) evaluated the climatology of precipitation of an ensemble of 10 RCM simulations in the entire continent, finding that all models simulate the seasonal mean and annual cycle accurately, with the exception of individual models in some regions. (Kim, Waliser et al. 2014) further evaluated the same ensemble of

RCMs showing that the models have higher skills in simulation of precipitation and temperature in the western rather than the eastern part of Africa. (Gbobaniyi, Sarr et al. 2014) conducted a similar analysis with focus on West Africa and demonstrated that RCMs reasonably simulate the occurrence and movement of the West African monsoon but that some of them exhibit biases of different extent that vary with model and location (Mascaro, White et al. 2015).

4.1.2 Bias Correction of the row Rcm Data

Climate models often provide biased representations of observed time series and, making correction procedures necessary (Navarro-Racines and Tarapues 2015). Bias correction actions employ a transformation algorithm for correcting RCM output. The underlying idea is the finding possible biases between observed and simulated climate variables, which are the basis for correcting both control and scenario RCM runs. Bias correction methods are assumed to be stationary, i.e., the modification algorithm and its parameterization for current climate conditions are also effective for future conditions.

The method used for bias correction of the study is the linear-scaling approach works with monthly correction values based on the changes between observed and present-day simulated values. By definition, corrected RCM simulations will faultlessly agree in their monthly mean values with the observations. Precipitation is corrected with a factor based on the ratio of long-term monthly mean observed and control run data;

$$p^*_{cuntr}(d) = P_{cuntr}(d).\{\mu_m(p_{obs}(d))/\mu_m(p_{cuntr}(d))\} \qquad (4.1)$$

$$p^*_{scen}(d) = p_{scen}(d).\{\mu_m(p_{obs}(d))/\mu_m(p_{cuntr}(d))\} \qquad (4.2)$$

$$T^*_{cuntr}(d) = T_{cuntr}(d) + \mu_m.\left(T_{obs}(d)\right) - \mu_m(T_{cuntr}(d)) \qquad (4.3)$$

$$T^*_{scen}(d) = T_{scen}(d) + \mu_m.\left(T_{obs}(d)\right) - \mu_m(T_{cuntr}(d)) \qquad (4.4)$$

Where;

* -Final bias-corrected

Cuntr - RCM simulated 1961-1990

μ - Monthly mean (location parameter of Gaussian distribution)

Scen - RCM-simulated 2005–2099

There were considerable differences in the ability of RCMs to reproduce temperature and precipitation data under current climate conditions. The biases were found to vary considerably depending on the analyzed climate variable. The RCMs tended to overestimate month of May, June, July, August, September and October and underestimate months of January, February, March, April, November, and December temperatures. The raw RCM temperature showed RCM-related variability with bias of -2.17734°C to +2.908826°C. There was a tendency of RCM to simulate too many low-intensity rain events. The raw RCM precipitation showed RCM-associated variability with bias of 0.7636mm to 17.09866mm.

4.2 Aquacrop

AquaCrop is the FAO crop-model to simulate harvest reaction to water. It is intended to balance ease, accuracy and robustness, and is predominantly suited to address conditions where water is a key controlling element in crop production. AquaCrop is a companion tool for a wide range of users and applications including yield prediction under climate change scenarios. AquaCrop is a fully revised form of the successful CropWat model. The main change between CropWat and AquaCrop is that the latter includes more innovative crop growth routines.

4.2.1 Setting up Aquacrop

To develop recommendation to advance water efficiency we can run field experiment and it will take many years before valid recommendation because it require different weather conditions, different crops and different management. So instead of field assessment we can run simulation with model. Simulation is performed by means of mathematical model. Mathematical models are simplified representation of a particular system. In Aquacrop the main interest is the field where the plants are cultivated. The plant production depend highly on the soil condition so there will be an interaction between the plant and the soil. The plant will grow if there is enough water on the soil and if the soil is poorly fertilized and dry there is no plant development. These interaction is the system which is modeled. The system (the interaction between plant and soil) also affected by management which (field and irrigation) which is fertility, when and in what amount to apply irrigation water. The system link with the outside world which is upper boundary. At upper boundary there is weather condition which describe what is the rain fall, how many energy's available to vaporize water and what is the concentration of carbon dioxide .At lower boundary ground water table is linked to the system in which water commencing the system drain and the water table near to the soil and subsoil then water move by capillary rise from the water table to the sub soil. Water table is not concern of Aquacrop but it intrusion in water quality of soil water is considered here.

Conditions in upper boundary

The upper boundary is about the weather condition and it consists reference evapotranspiration, rainfall, minimum and maximum temperature and annual co_2 concentration. From metrological data recorded in wonji shoa station is used to compute reference evapotranspiration.it express the evaporating power of the atmosphere.it determine the rate of transpiration and evaporation.in Aquacrop it can be calculated from metrological data. Next to EtoAquacrop require minimum and maximum temperature.it required to calculate growing degree days which determine the speed of crop development. They are also cold and heat stress in Aquacrop which affect yield and biomass production. Eto, minimum and maximum temperature can be enter daily,10 daily or monthly. However Aquacrop will need, work and simulate in daily time steps. In Wonjishoa case both base line and future data (Eto, minimum and maximum temperature and rainfall) are in daily steps. Aquacrop also require rainfall data to update daily water balance and to simulate water stress. Finally Aquacrop need mean annual co_2 concentration because it affects biomass making and crop transpiration. It consists recorded and projected(future) concentrations. The later one is used for climate alteration scenarios.

The structure of climate file

Aquacrop contain a data base which climatic data is stored. In one hand we have evaporating power of the atmosphere which is stored on Eto file. We also have Tnx file which contain minimum and maximum air temperature. Next we have Flu files which contains rainfall and finally we have co_2file which contains long record mean annual co_2 concentration. These four file contain climatic data. Finally there is a climate file which is a Cli file and it just not contain any data but tells which is Eto, Tnx, Plu and co_2 file linked to that particular station.

Climate data

Importing climatic data to the Aquacrop include preparing text file with climate data, import climatic data from text file in Aquacrop's data base and create climatic file. To calculate growing degree days, air temperature is responsible to decide the progress of crop growth and phenology, maximum and minimum temperatures are mandatory. During winter, it is sufficient to create adjustments in crop transpiration. Air temperature is needed for manipulating the stress of heat in addition cold so as to affect the crop pollination. Precipitation data is essential here to renovate the soil water balance and to estimate soil water stresses which are disturbing the growth of plant. Data can be daily, 10-daily or monthly. By means of CO2 files (estimated from intergovernmental panel on climate change (IPCC)), it enables testing the crop response under climate change scenarios. From dew point temperature, air humidity is usually obtained.

Solar radiation (*Rs*) can be anticipated from difference between maximum temperature (*Tmax*) and minimum temperature (*Tmin*). It involves extraterrestrial radiation (*Ra*) for the certain location and time of the year that can be calculated by the following formula

$$Rs \approx KRs\sqrt{(T_{max} - T_{min})}Ra \qquad 4.5$$

Wind speed is generally calculated at range of heights and further has to be transformed to 2 meter reference height. A measure of evaporative pressure of environment is known as ETo. It also decides both crop transpiration and soil evaporation rate. To determine ETo, Aquacrop requires station characteristics like latitude, altitude and location. It can be calculated by means of built-in ETo calculator. The following parameters are used to import the climatic data in AquaCrop database.

Climatic database includes PLU file (rainfall data), ETo (Evapotranspiration data), TNX file (Maximum and minimum Temperature data and Co2 file (Co2 elevation data) that are finally stored and created as .cli file.

Table 1: Climatic data parameters required by aquacrop

Attributes	Measure
Maximum Temperature	°C
Minimum Temperature	°C
Relative Humidity	(max, mean, min) %
Evapotranspiration	Mm
Wind Velocity	km/hr or m/sec

Crop

Aquacrop simulate the interaction between crop and soil. Management considered as well since it affect the interaction between them. In Aquacrop there are two parameters conservative and cultivar specific andless conservative parameters. When we load crop file Aquacrop load conservative parameters which are crop specific, do not change maternally with time, management practice, geographical location, climate or cultivar. They are valid in all cultivar and environment. So we don’t need to calibrate and validate it. The parameters which need to be calibrate and validation are the cultivar specific and less conservatives ones includes field management, planting mode, condition in the soil, and climate.

But non conservative parameters are the parameters, which are cultivator specific, can be influenced by crop field rule, planting node, state of soil etc. Theses parameters necessarily to be tuned that is calibrated to the cultivator or the environment (Vanuytrecht, Hsiao et al. 2014).

Table 2: Crop parameters required by aquacrop

Parameters	Unit
Day 1 after transplanting	Date
Initial canopy cover	%
Canopy size transplanted seedling	cm2 / plant
plant density	plants/ha
Maximum Canopy Cover	%
Root Deepening	M
Harvest Index	%
Biomass production	%
Canopy decline in season	%
KcTr	Unit less
WP* g m-2	gm^{-2}

The crop parameters are more needful for AquaCrop in order to acquire more efficiency. If stress in the soil fertility is considered, then the value of biomass production, average canopy decline and maximum canopy cover should be calibrated. AquaCrop model has been built to forecast the yield of sugarcane at the distinct field with requirement of limited data. In advanced simulations like field apart or farm up to the regional level, improved climatic weather record, crop characteristics data, enhanced soil data, and some organizing practices are required.

Parameters affected by field management

Type of planting method; it may be direct sowing or transplanting. If the type of sowing is direct sowing the size of canopy cover by germinating seed can be known by Aquacrop.it is conservative parameters. When the sowing method is transplanting the size of canopy cover is influenced by on the time it spend on nursery site so we need to specify it. In wonji shoa plantation transplanting is the method to planting.

Plant density; which is important to calculate initial and canopy cover ($cc_{o_{\circ}}$) cc for canopy cover note for initial. Initial canopy cover is the moment of emergence. Aquacrop need that for describing the canopy development in function time. cc_ocan be calculated as the plant density times the size of canopy cover per seedling.

Plant density also needed to calculate maximum canopy cover cc_x that can be reached x is for maximum. Maximum canopy cover is reached at the mid-season and when plant density is dense it about 100%. And when plant density is thin it’s much more less. The final parameter that is disturbed by planting is the time to 90% seedlings.

The time to 90% seedling emergence; we have to specify the time since its affected by field preparation, soil temperature and soil water content. The time needed for 90% seedling of the wonjishoa case is about 3 month.

Parameters affected by cultivar

Many of crops cultivar differences a rises from the timing of development stages. So we need to specify the time to reach maximum canopy cover, beginning of canopy senescence, physiological maturity, start of flowering or yield formation and duration of flowering.

Parameters affected by conditions in soil profile

Maximum rooting depth and the time to reach that depth is considered here. The rooting depth and the time to reach it affected by soil physical and chemical characteristics such as temperature, mechanical impendence, aeration, ph, salinity, high level of aluminum and manganese. What we need to specify is the time to reach the maximum depth and the maximum rooting depth itself. Aquacrop use the concept of effective rooting depth that is the soil depth where major crop water uptake takes place. Minimum effective rooting depth is considered here is not zero its about 0.2 or 0.3m where the germinated seed can extract water. The effective rooting depth in wonjishoa plantation is 0.85-2m but when its 5 routine it sometimes reach 3.2 m.

Cultivar class conservative crop parameters

Some of the parameters assigned to conservative one may vary in little with different cultivar of crop species. This is the result of plant breeding and bio technology. One of cultivar class conservative crop parameters changed in the future is reference harvest index (Hio). Here in wonjishoa it is 20.

Field management

Aquacrop simulate crop and soil interaction. Since it affected by field management. It must be considered as well. There are parameters which vary with type of field management. In Aquacrop various types of field management are considered and include field surface practice, application of mulches and effect of soil fertility.

Field surface practice

These are practice which used to reduce surface runoff. Aquacrop have methods to estimates surface runoff. Surface runoff is the part of rainfall might lost by surface run-off from the field and dose not infiltrate. Surface runoff is simulated in Aquacrop by the curve number (CN) method from SCS of the USDA. In Aquacrop infiltration rate is considered to calculate CN. The curve number is low for high infiltration rate. If infiltration rate of the soil is low the curve number will increases which will generate more runoff. Surface runoff influenced by on the soil type which is curve number and the overall of rainfall. There is always a rainfall which does not generate a surface runoff. These amount is low for soil with high curve number and large for soil of low curve number. That amount which does not produce runoff varies with the wetness of the top soil. If the top soil is wet then Aquacrop will adjust the curve number in such a way that there is more run-off and the rainfall that does not generate run-off become smaller. When the top soil is dry more water is stored and the curve number drop down. Given the infiltration rate Aquacrop will select the curve number but that curve number vary with the condition of the top soil.

Soil fertility

Soil fertility has great effect on the canopy development and water production. When there is low fertility, the canopy cover become less developed. When there is unlimited soil stress and no soil stress there will be a nice canopy cover over time. With limited soil stress the canopy cover will be less. These is due to three reason first, due to slower canopy cover development and it takes longer to reach maximum canopy cover. Second there will be less dense canopy and the maximum cover become lower. The third one is during the crop cycle the canopy cover is already decline. In Aquacrop it described by soil fertility stress coefficient ks_f. First $ks_{exp,f}$, Which is affect canopy growth coefficient. The second isks_{ccx} which affect the maximum canopy cover and the third one is $fc_{decline}$ which describe the decline of the canopy with time.

Soil fertility also affect water productivity. When there is drop in soil fertility, the water productivity decreases. And biomass production per unit water reduces. These expressed by stress coefficient.

$$Wp_{adj} = Ks_{wp} * wp \qquad 4.6$$

The effect of soil fertility on water productivity is not the same throughout the season. In the beginning of the season no effect is seen in the water productivity since sufficient nutrient are available in the root zone.

After some biomass develops, progressive depletion of nutrients from the reservoir will be appear and as a result the water productivity declines. The application of fertilizer is specified here. In wonjishoa case the fertilizer is with no stress which is unlimited.

Irrigation management

There are parameters required by Aquacrops which vary with irrigation mode. They are four irrigation mode. The first is absence of irrigation, which is the default one. In Aquacrop we can determine the net irrigation water management which is the other mode of irrigation. There is also the estimation of the existing irrigation schedule. Here we specify the time (when to apply), the quantity and quality of the water. The last mode is to ask in the software to generate irrigation schedule. By specifying the time criterion, the software will determine when to apply, and by specifying the depth criterion the amount of water that will be irrigated will be generated.

Determination of net irrigation requirement (I_{net})

The resolution of net irrigation makes use of threshold. It's the allowable root zone depletion. When in the lack of rainfall the irrigation volume drops below the allowable root zone then small amount of water will be injected in the root zone to keep the soil water content at that level for such day. Toward the end of the season, the sum of the added water is the net irrigation.

$$I_{net}=\sum water\ added \qquad 4.7$$

These are net requirement because does not consider extra water that has to be practical to the field to account for conveyance losses or the uneven distribution of irrigation water on the field. To run Aquacrop in the net irrigation mode, we need to specify the allowable root zone depletion which is expressed in fraction of RAW (rarely available water). RAW is zero when the soil water content is in field capacity and 100% at the threshold for stomatal closure. So the allowable root zone depletion is expressed in percentage of RAW. The RAW of the wonjishoa sugar plantation is

Irrigation method

To assess the irrigation schedule or generate irrigation schedule Aquacrop need the method of irrigation. The knowledge of method required because it determine which fraction of the soil surface is wetted. It’s 40-60% in furrow, 30% in drip, 100% in sprinkler and basin irrigation. In wonjishoa the technique of irrigation is furrow.

Irrigation schedule

Here it used to evaluate the existing irrigation schedule. We have to give some data to the software like when the irrigation took place, how much water is functional and the quality of the water. For the amount of water applied Aquacrop require the net amount. The existing irrigation schedule for wonjishoa plantation is evaluated here.

Generation of irrigation schedule

The mode generation of irrigation schedule is used to design irrigation schedule and checking the existing particular irrigation strategies. It consists selecting time criterion and the depth criterion. The time criterion determine when water has to apply and the depth criterion how much water to apply. The criterion may vary during the crop cycle. Especially the time criterion will often vary in different growth stages or in the function of weather condition.

There are several time criterions and the first one is when the root zone depletion reaches a specific threshold. It’s expressed by mm or % of RAW. When the water content reach below that threshold, water will be added. The second criterion is fixed interval, every ten or fifteen days for example. It is useful in the case of rotational method of irrigation among irrigation groups. The fixed interval can be changed during the season and might be shorter when the weather become hotter and the crops are more developed. The last criterion is useful in paddy rice irrigation. The criterion is water is applied when the water layer between bunds drops below the minimum level. The time criterion of wonjishoa plantation is both root zone depletion and fixed interval which is flexible with time. The interval changes between 10 to 30 days based on the soil water content and changes with weather condition.

There are two depth criterion one a threshold is reached,triggering irrigation return the water content in the root zone to field capacity. In Aquacrop we can even specify that an extra amount of water has to be added for example lichening salt out of root zone. Or even we don't go exactly back to field capacity but remain a certain amount below field capacity for example 10 mm to take to account rain in the next day. The other depth criterion is fixed application dose. That does selected in function of local practice, soil and crop parameters and irrigation method. When specifying fixed application dose, only the net depth is specified. The net application depth does not consider extra water that has to be applied to the field to account for conveyance losses or runoff from the field. Indicative value for irrigation interval and application depth can be obtained from the help of the following graph by considering weather condition, crop canopy, rooting depth and soil physical characteristics.

Wonjishoa plantation uses furrow irrigation methods. The depth of application of water varies from season to season and from one site to another site. The soil of wonji shoa differs from one site to another. So the amount of water to apply at one site may be higher/less than the next site depend on the soil water content . the soil of wonjishoa plantation contain 70 % heavy clay.

Soil profile

AquaCrop embraces physical as well as chemical parameters of the soil profile which are shown in Table III. Sampling can be conducted from 120 cm soil depth (Vanuytrecht, Hsiao et al. 2014). Usually soil profile study was allowed to demonstrate the soil characteristics at experimental field and determined the analysis of physicochemical belongings. In this model, the condition of soil water in the lower, middle and upper positions has been measured as the input of the AquaCrop model in order to predict the water use effectiveness of the sugarcane.

Since Aquacrop simulate the relation between soil and crop interaction also affected by management, the soil characteristics must be described. To describe soil water balance and soil water retention in the root zone, we need to know soil water content at; saturation, field capacity and permanent wilting point. To describe soil water movement, Aquacrops requires to know saturated hydraulic conductivity and soil type. The soil can be composed of several horizon and hence for each horizons Aquaccrop requires physical characteristics (Pawar, Kale et al. 2017). Knowing soil physical characteristics (soil water content at SAT, FC and PWP and hydraulic conductivity), by using that information Aquacrop will drive other soil characteristics. These soil characteristics which obtained by using soil water content include; TAW which determine the size of soil reservoir in which water can be stored, REW which is readily evaporative water which is required to calculate soil evaporation and soil type.

Characteristics determined by Aqucrop by using hydraulic conductivity are capillary rise, drainage(tau) and curve number (surface runoff). The required soil physical features can be attained from the field, indicative values and pedo-transfer function to derive them from soil textural information's. In wonjisowa plantation the whole soil physical characteristics are come from WonjiShoa sugarcane estate research center.

Table 3: Soil parameters

Parameters	Unit
Thickness	M
Saturation vol	vol %
FC	vol %
Water Productivity	vol %
K sat (saturation)	mm/day
Penetrability	%
Gravel	%
Organic matter	%

				Retation in fine fraction			Hydraulic Conductivity
Horizon	Discription	Thicknes	TAW mm/m	PWP	FC	SAT	ksat mm/day
1	clay	1.5	150	39	54	55	35
2	silt clay	0.75	180	32	50	54	100
3	silt	1	240	9	33	43	500

Condition in the lower boundary

The lower boundary is all about the depth and the quality of the ground table. By knowing the depth of the ground table and its quality, Aquacrop can simulate the movement of water and salt from the ground water to the root zone. The condition at the lower boundary can be constant or vary with time.

The ground water of WSSE is very shallow, experiencing great spatio-seasonal fluctuations and showed a rising trend. Such characteristics of GWTD are expected to negatively impact the socio-economics and environment of the region; thus, a concern for the sustainability of the sugar estate. The mean average GWTD of the study area ranged between 0.2 m and 2.0 m; thus, all plantation fields are classified to be shallow. The ground water data of Wonji shoa plantation used for Aqoacrop is groundwater table with constant depth and salinity (1.5m and2.5ds/m)

5. RESULT AND DISSCUTION

5.1 Climate Projection

The projected climate result during base line and future period is described here. The result of downscaled RCM of more than 15 models for the rcp4.5 (Medium representative concentration pathway) and rcp8.5 (high-representative concentration pathway) Scenarios from 1990 to 2099 compared with the base line (1990-2016) period data get from wonjishoa sugar cane estate research center.

5.1.1Base line Scenario

Maximum Temperature

The monthly mean maximum temperature obtained from RCM model (CORDEX) and with bias correcting gives the following results for the baseline period (1990-2016) of both in rcp4.5 and rcp8.5 emission scenarios as shown Figure

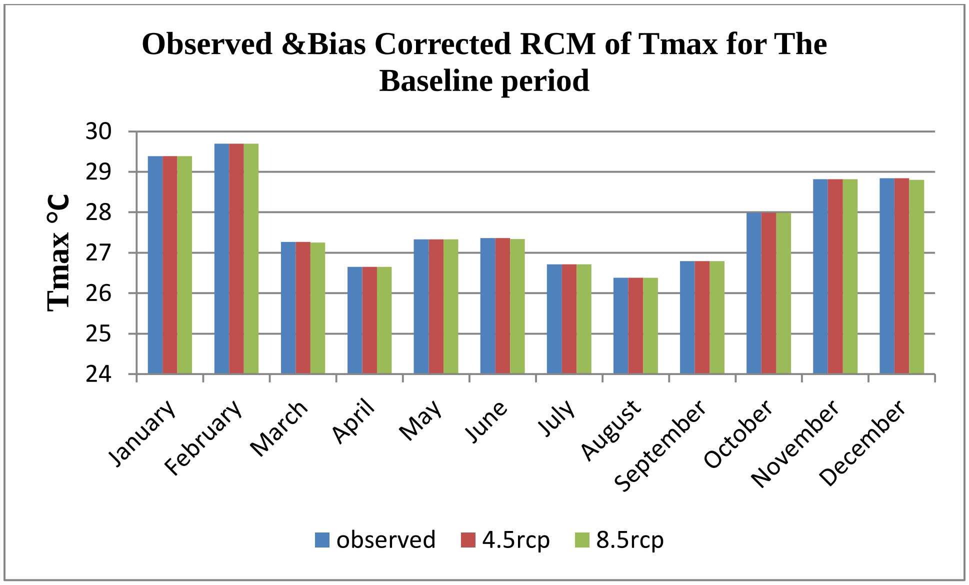


Figure 5: observed and bias corrected RCM monthly mean Tmax for baseline period

Precipitation

Bias corrected RCM model result performs reasonably well in estimating the mean monthly precipitation satisfactory given the fact that precipitation downscaling is necessarily more problematic than temperature. The monthly precipitation downscaled for the baseline period is shown in Figure below.

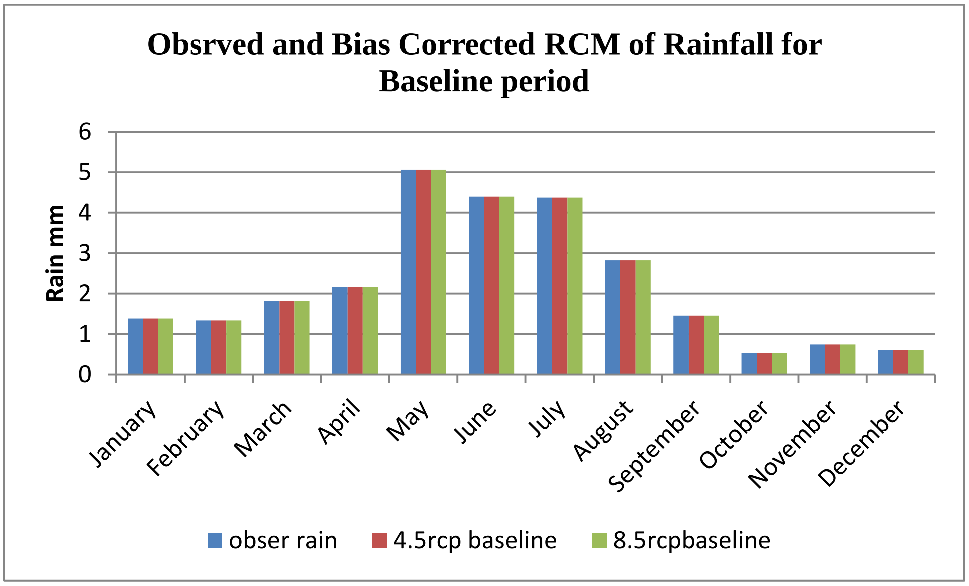


Figure 6: observed and bias corrected RCM monthly mean precipitation of baseline period

Minimum temperature

The monthly minimum temperature for 4.5 and 8.5 RCP scenarios in the baseline period shows a reasonably good agreement with the observed minimum temperature for all months as shown in Figure below.

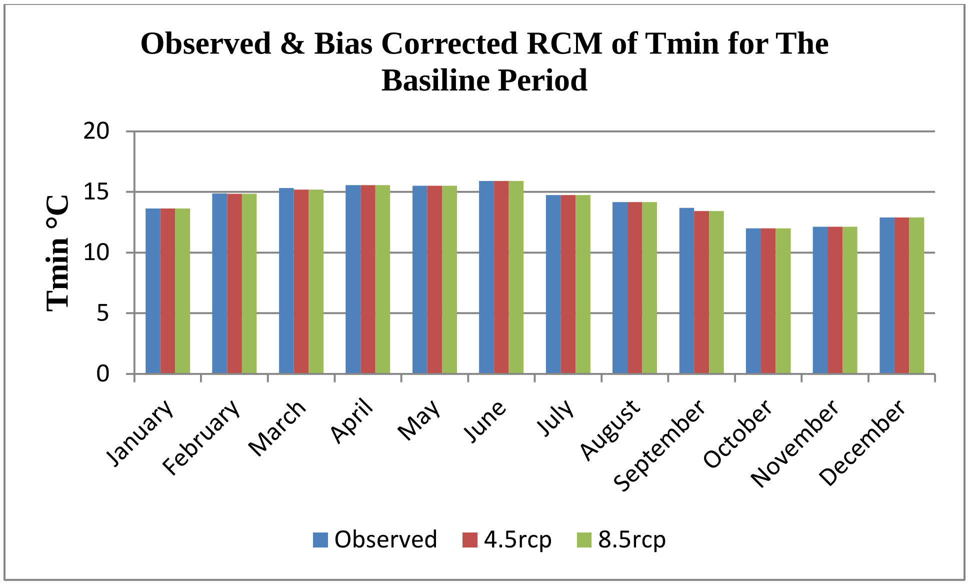


Figure 7: Observed and bias corrected monthly mean RCM of Tmin for baseline period.

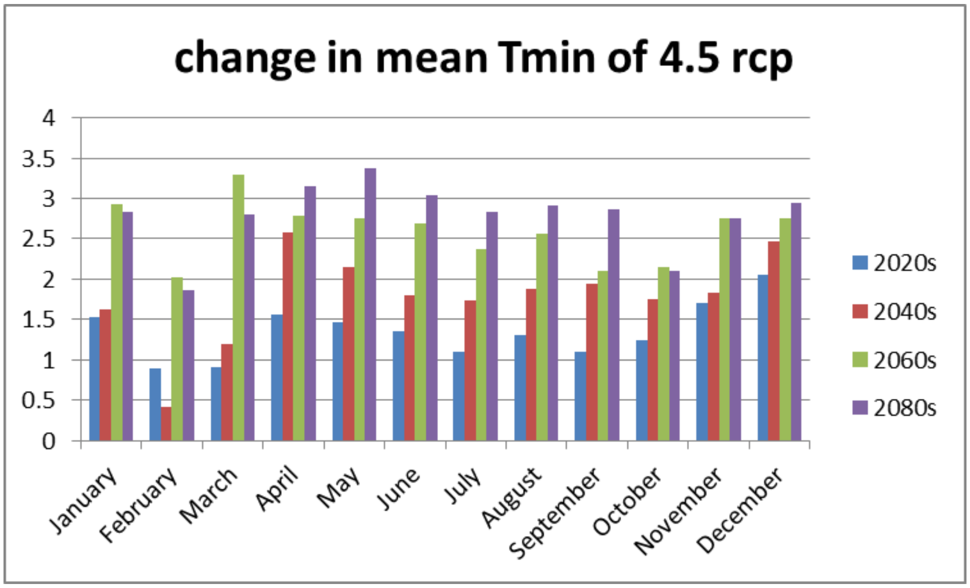
5.1.2 Downscaled RCM for Future Scenario

The climate scenario result for future period was developed from downscaled GCM for two representative concentration pathway (4.5and 8.5 rcp) for 90 years and the analysis was done based on four 20-year periods centered on the2020s (2020-2039), 2040s (2040-2059), 2060s (2060-2079) and 2080s (2080-2099). All the comparisons in the following analysis were done with respect to the baseline period (1990-2016) data at wonji shoa research center.

Minimum temperature

The downscaled minimum temperature shows an increasing trend for all months in all future time horizons for both 4.5 rcp and 8.5 scenarios. The average annual minimum temperature in 2020s will be increased by 1.35°C and 1.59 °C for 4.5rcp and 8.5rcp scenario respectively. For the 2040s periods the average annual minimum temperature will be increased by 1.79°C and 2.7°C for 4.5rcp and 8.5rcp scenario respectively. For the 2060s periods the average annual minimum temperature will be increased by 2.59°C and 3.63°C for 4.5rcp and 8.5rcp scenario respectively. For the late 21 century the average annual minimum temperature will be increased by 2.79°C and 4.09°C for 4.5rcp and 8.5rcp scenario respectively .Increasing minimum temperature showed more variation at the monthly time step with arrange from 0.7°C to 2.05°C in 2020s, 0.4.°C to 3.3°C in 2040s, 2.01°C to 4.16°C in 2060s and 1.85°C to 4.42°C in 2080s.

(a)



(b)

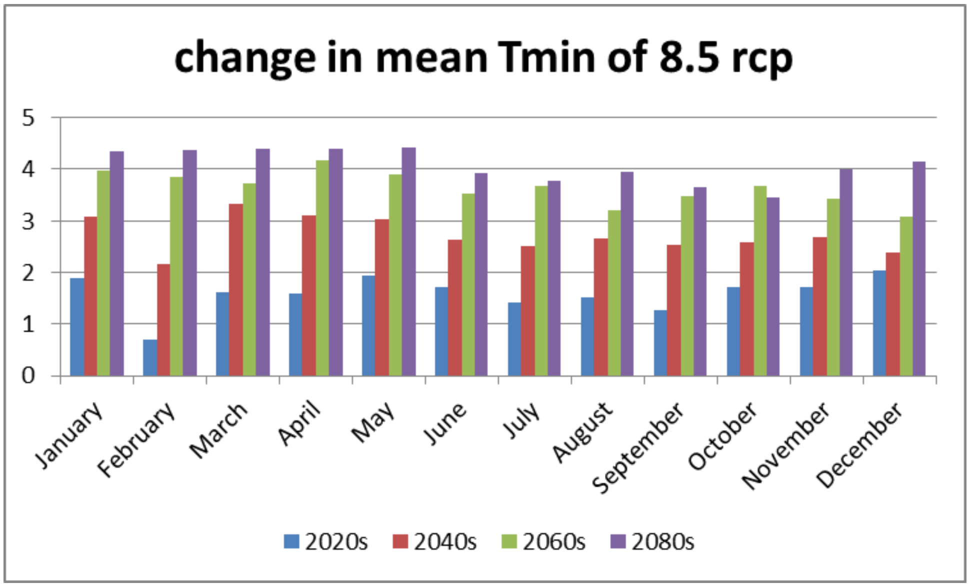
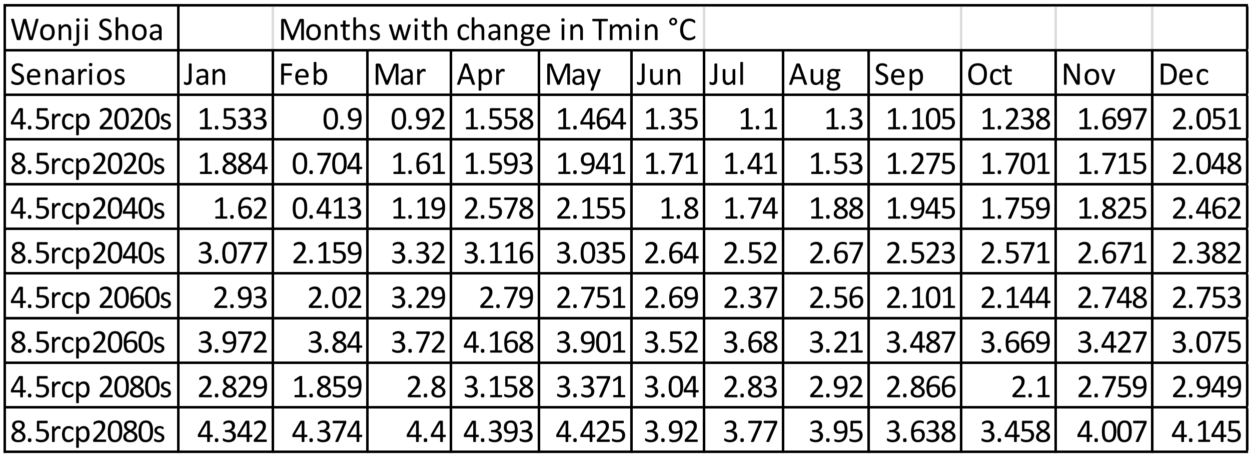


Figure 8: Change in Tmin(2011-2099) at wonjishoa, (a) & (b) for both scenarios

Table 4: Monthly and Annual Tmin changes (°C) under various scenarios

(a)



Wonji Shoa		Months with change in Tmin °C									
Senarios	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.5rcp 2020s	1.533	0.9	0.92	1.558	1.464	1.35	1.1	1.3	1.105	1.238	1.697	2.051
8.5rcp2020s	1.884	0.704	1.61	1.593	1.941	1.71	1.41	1.53	1.275	1.701	1.715	2.048
4.5rcp2040s	1.62	0.413	1.19	2.578	2.155	1.8	1.74	1.88	1.945	1.759	1.825	2.462
8.5rcp2040s	3.077	2.159	3.32	3.116	3.035	2.64	2.52	2.67	2.523	2.571	2.671	2.382
4.5rcp 2060s	2.93	2.02	3.29	2.79	2.751	2.69	2.37	2.56	2.101	2.144	2.748	2.753
8.5rcp2060s	3.972	3.84	3.72	4.168	3.901	3.52	3.68	3.21	3.487	3.669	3.427	3.075
4.5rcp 2080s	2.829	1.859	2.8	3.158	3.371	3.04	2.83	2.92	2.866	2.1	2.759	2.949
8.5rcp2080s	4.342	4.374	4.4	4.393	4.425	3.92	3.77	3.95	3.638	3.458	4.007	4.145

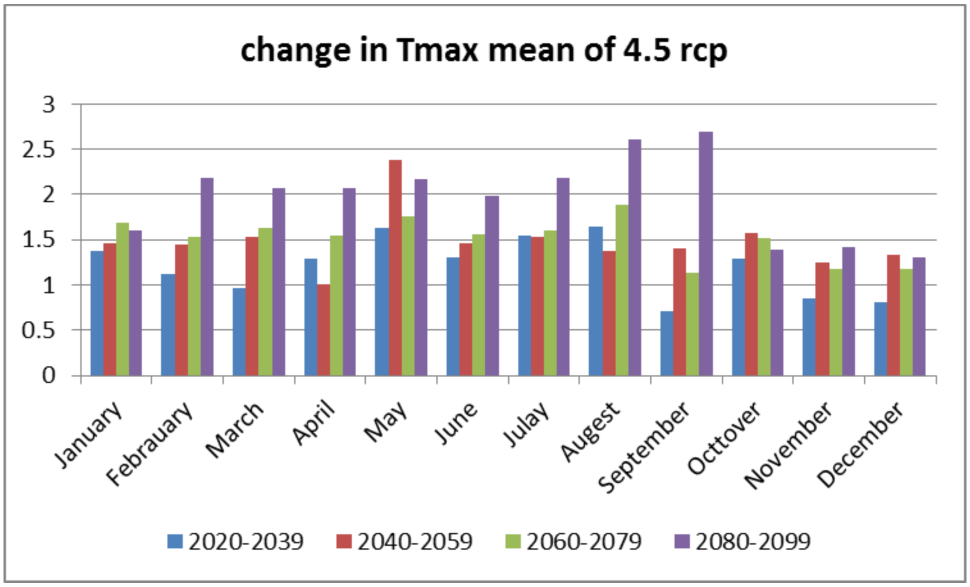
(b)

Scenarios	Annual value
2020s4.5rcp	1.351
2020 8.5rcp	1.59
2040s4.5rcp	1.786
20408.5rcp	2.723
2060s4.5rcp	2.595
2060s8.5rcp	3.639
2080s4.5rcp	2.79
2080s8.5rcp	4.067

Maximum Temperature

For WonjiShoa the overall analysis (2011-2099) of maximum temperature showed that there may be increasing trends in both scenarios (4.5rcp and 8.5rcp). The average annual maximum temperature in 2020s will be increased by 1.21°C and 1.16°C for 4.5rcp and 8.5rcp scenario respectively. For the 2040s periods the average annual maximum temperature will be increased by 1.48°C and 1.93°C for 4.5rcp and 8.5rcp scenario respectively. For the 2060s periods the average annual maximum temperature will be increased by 1.52°Cand 2.98°C for 4.5rcp and 8.5rcp scenario respectively. For the 2068s periods the average annual maximum temperature will be increased by 1.97°Cand 4.17°C for 4.5rcp and 8.5rcp scenario respectively. Increasing maximum temperature showed more variation at the monthly time step with arrange from 0.8°C to 1.45°C in 2020s, 1.01°C to 2.6°C in 2040s, 1.13°C to 3.66°C in 2060s and 1.30°C to 4.68°C in 2080s.

(a)



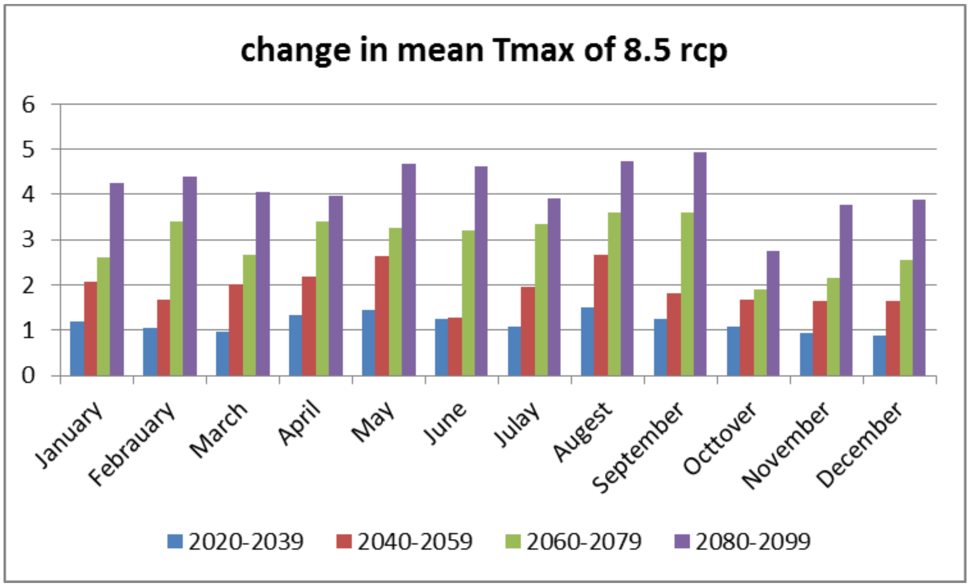


Figure 9: Change in Tmax (2011-2099) at wonjishoa, (a) & (b) for both scenarios

Table 5: Monthly and Annual Tmax changes (°C) under various scenarios (a and b)

(a)

Secenarios		change in mean of Tmax °C										
2020-2039	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.5rcp	1.369	1.11	0.97	1.295	1.625	1.306	1.547	1.638	0.713	1.2885	0.849	0.8091
8.5rcp	1.204	1.06	0.98	1.34	1.453	1.252	1.067	1.512	1.244	1.089	0.924	0.8678
2040-2059												
4.5rcp	1.464	1.45	1.54	1.012	2.378	1.462	1.532	1.38	1.405	1.571	1.246	1.3312
8.5rcp	2.058	1.67	2.01	2.186	2.633	1.274	1.962	2.654	1.821	1.664	1.643	1.6486
2060-2079												
4.5rcp	1.686	1.53	1.64	1.552	1.761	1.559	1.598	1.887	1.132	1.5211	1.179	1.1806
8.5rcp	2.597	3.41	2.68	3.416	3.269	3.192	3.359	3.606	3.598	1.8926	2.169	2.5661
2080-2099												
4.5rcp	1.603	2.19	2.07	2.078	2.169	1.987	2.178	2.606	2.689	1.3866	1.415	1.3022
8.5rcp	4.256	4.39	4.07	3.975	4.676	4.633	3.905	4.738	4.943	2.7482	3.777	3.9

(b)

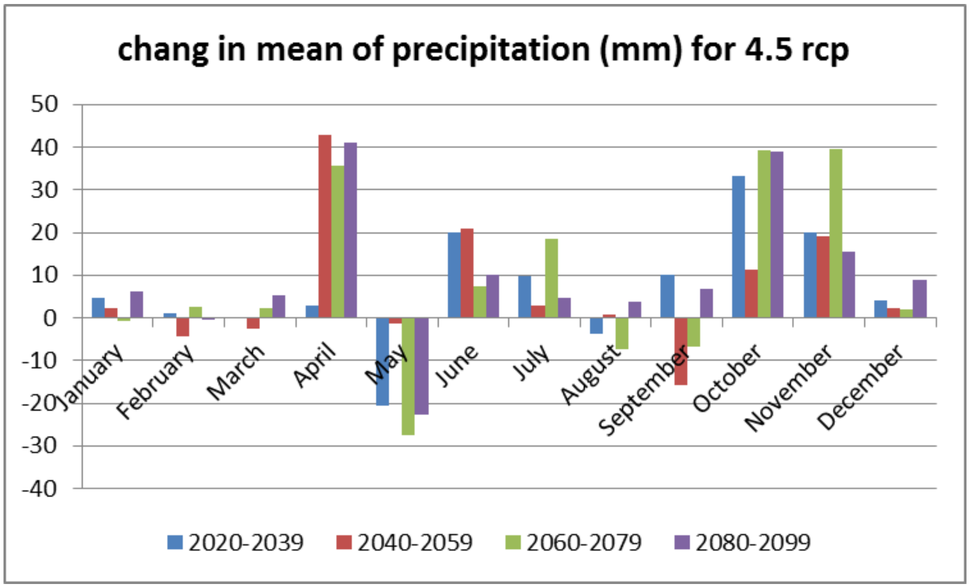
Scenarios	Annual value
2020s4.5rcp	1.210508982
2020 8.5rcp	1.165379048
2040s4.5rcp	1.480667591
20408.5rcp	1.935691675
2060s4.5rcp	1.518588384
2060s8.5rcp	2.979337057
2080s4.5rcp	1.972674529
2080s8.5rcp	4.16778183

Precipitation

The precipitation projection exhibited an increase in average mean precipitation in periods (2020s, 2040s ,2060s and 2080s). As can be shown in Figure (a) and (b) below, in all periods there may be a decrease in precipitation for months May & September and increase in all other months for both scenarios (4.5rcp and 8.5rcp). The overall effect in 2020s may be an increase of average annual precipitation by 6.85mm in the 4.5rcp scenario and 1.57mm in the 8.5rcp scenario. In 2020s, the maximum monthly average precipitation observed in October which is increase up to 33.3mm for 4.5 rcp&November which is increased by 19.7mm in 8.5rcp scenarios . The overall effect in 2040s may be an increase of average annual precipitation by 6.6mm in the 4.5 scenario and 3.4mm in the 8.5 scenario. In 2040s, the maximum monthly average precipitation may reach up to 43.04mm for April in the 4.5 scenario and 31.6mmfor in the 8.5 scenario. In 2060s the 4.5rcp and 8.5rcp scenarios showed an increase in average annual precipitation amount by 8.83mm and 11.07mmrespectively. In the 2060s, the increase in monthly average precipitation may reach up to 39.6 mm for November in the 4.5rcp scenario and

37.15mm for October in the 8.5 scenario. In 2080s the overall effect may be an increase of average annual precipitation by 9.88mm in the 4.5 scenario and 18.34mm in the 8.5 scenario. In the 2080s, the increase in monthly average precipitation may reach up to 41.02mm for April in the 4.5rcp scenario and 68.71mm for October in the 8.5 scenario.

(a)



(b)

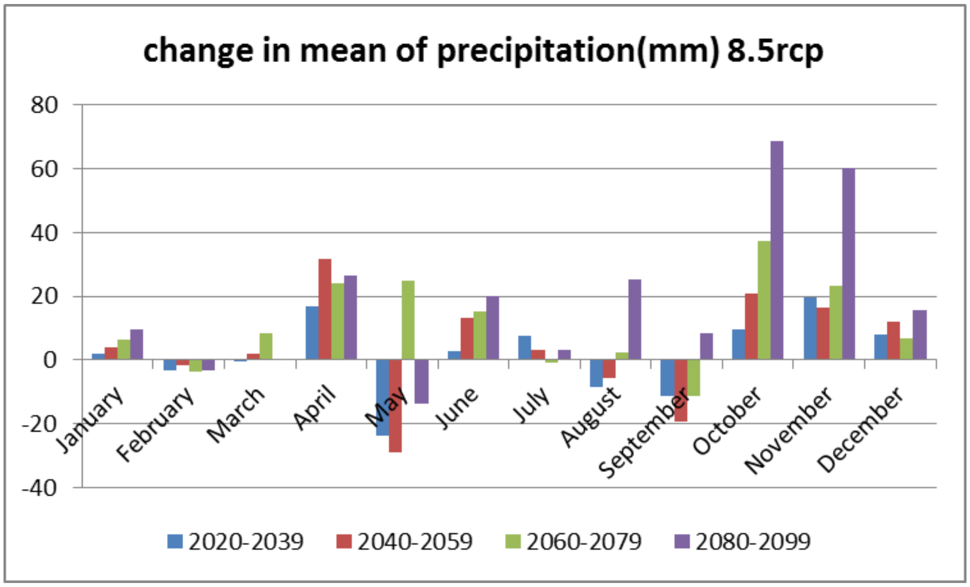


Figure 10: change in mean of precipitation at WonjiShoa (a) & (b) for both Scenarios

Table 6: Annual and monthly precipitation changes under various scenarios

			change in mean of prcipitation (mm)									
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020-2039												
4.5	4.619	1.09	0.21	2.87	-21	20.1	9.878	-3.735	10.26	33.3	20.03	4.22
8.5	1.839	-3.2	-0.5	16.9	-24	2.77	7.655	-8.404	-11.4	9.48	19.72	7.85
2040-2059												
4.5	2.262	-4.3	-2.4	43	-1.3	20.9	2.879	0.82	-15.8	11.5	19.31	2.42
8.5	3.843	-1.8	1.92	31.6	-29	13.3	3.328	-5.477	-19.1	20.7	16.62	11.9
2060-2079												
4.5	-0.74	2.76	2.42	35.6	-27	7.47	18.63	-7.189	-6.72	39.3	39.63	2.15
8.5	6.237	-3.6	8.22	24	24.8	15.3	-0.67	2.472	-11.2	37.2	23.34	6.82
2080-2099												
4.5	6.231	-0.3	5.27	41	-23	10.2	4.61	3.81	6.849	39.1	15.56	8.94
8.5	9.457	-3.4	0.47	26.5	-14	20	3.301	25.45	8.224	68.7	60.17	15.7

5.2 Aquacrop Model Results

5.2.1 Calibration and Uncertainty Analysis

Crop simulations were based on the cultivar N-14, which occupied 28 % of the sugarcane area at Wonjishoa during the 2015/2016 season. Calibration of the model to this cultivar was done using the field data obtained in wonji shoa. Model performance was evaluated using index of agreement, root mean square error (RMSE) and the coefficient of determination (R2). The RMSE represents a measure of the overall, or it is the mean value of O i. mean, deviation between observed and simulated values, that is, a synthetic indicator of the absolute model uncertainty. It takes the same units of the variable being simulated. Values of mean residual and mean relative error close to zero indicate small differences between simulated and observed mean thus indicating little systematic deviation or bias in the entire data set hence the better the model's fit. Values of RMSE close to zero rather express precision and reliability of the simulation for observed estimation points (Hsiao, Heng et al. 2009).

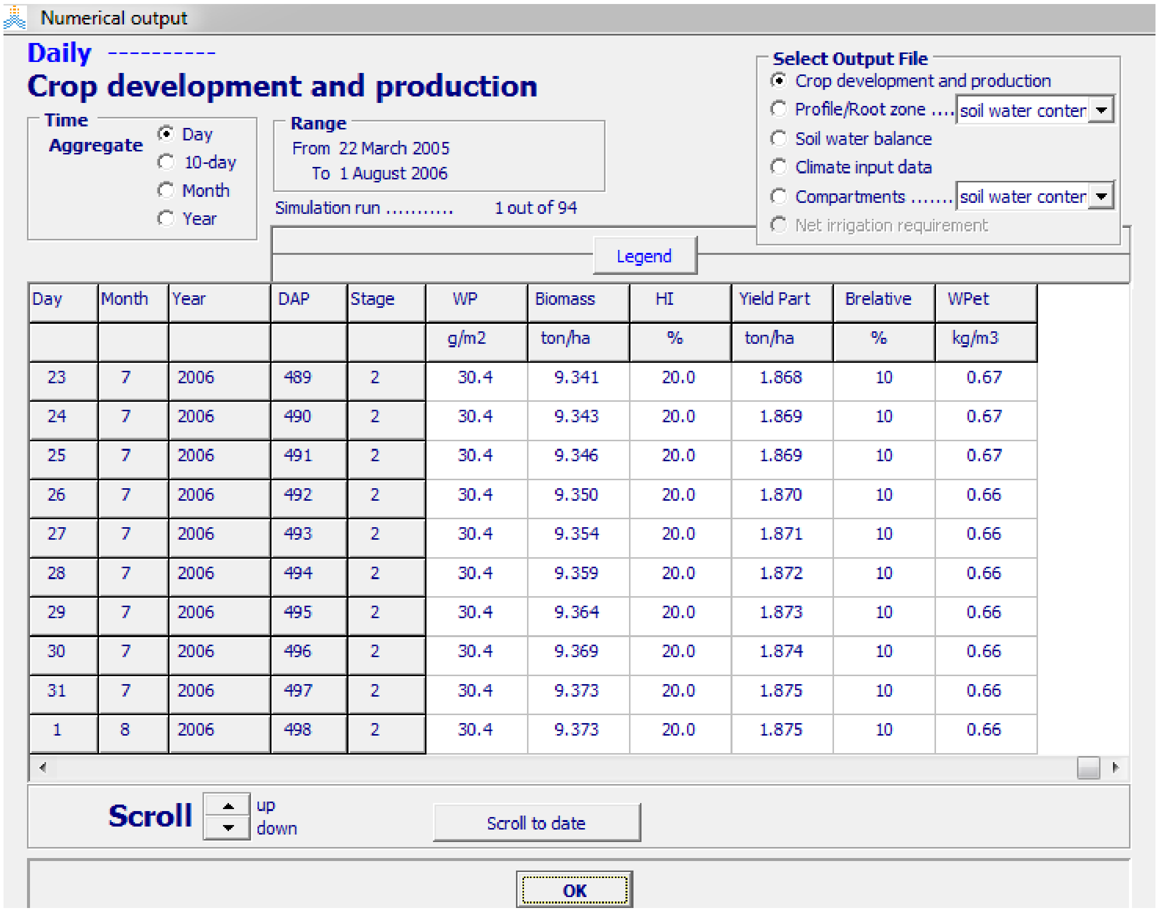
Coefficient of determination (R2) estimates the combined dispersion against the single dispersion of the observed and simulated series. The range of R2 lies between 0 and 1 which describes how much of the observed dispersion is explained by the simulation. A value of zero means no correlation at all whereas a value of 1 means that the dispersion of the simulated is equal to that of the observation. The fact that only the dispersion is quantified is one of the major drawbacks of R2 if it is considered alone.

$$R^2 = \sum_{i=1}^{n} (Si - Oi)〗\,\hat{}2(Si - S) / \sqrt{\sum (Oi - O)^2 \quad \sqrt{\sum_{i=1}^{n} (Si - S)^2}}$$

AquaCrop calibration; The simulations performed focused on total biomass and yields. Trough repeated simulation runs and output comparison (biomass and grain yields) of simulated versus observed yields, a set of values were arrived at for conservative parameters which seemed most appropriate and gave satisfactory results for the period of 1990-2006.

Model validation for validation, data from 2007-2016 were used. There was a good fit between the simulated aboveground biomass and grain yield agreed well with their corresponding observed data for all treatments during successful seasons had better fit (R2=0.89).

Aquacrop Model Results



Daily ----------

Crop development and production

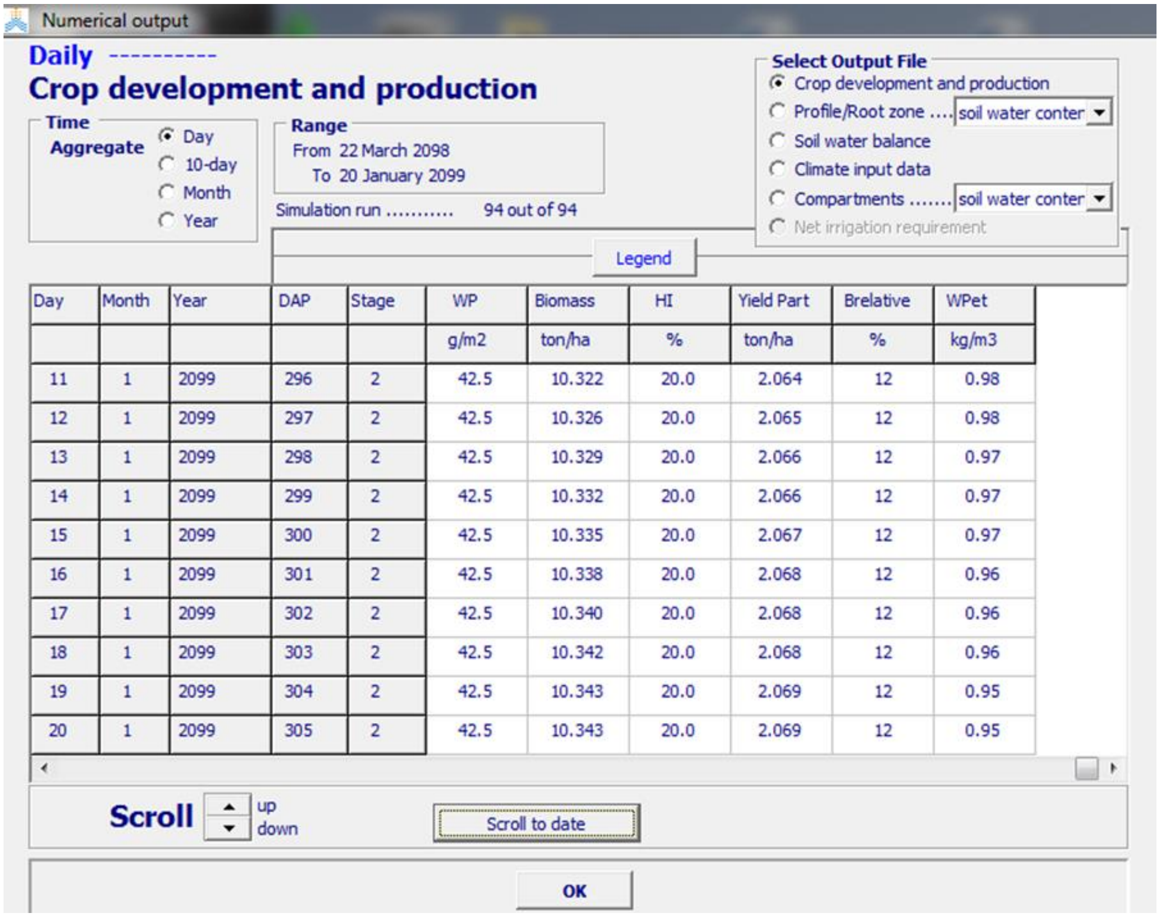
Time Aggregate
● Day
○ 10-day
○ Month
○ Year

Range
From 22 March 2005
To 1 August 2006

Simulation run .... 1 out of 94

Select Output File
● Crop development and production
○ Profile/Root zone .... soil water conter
○ Soil water balance
○ Climate input data
○ Compartments .... soil water conter
○ Net irrigation requirement

Day	Month	Year	DAP	Stage	WP	Biomass	HI	Yield Part	Brelative	WPet
					g/m2	ton/ha	%	ton/ha	%	kg/m3
23	7	2006	489	2	30.4	9.341	20.0	1.868	10	0.67
24	7	2006	490	2	30.4	9.343	20.0	1.869	10	0.67
25	7	2006	491	2	30.4	9.346	20.0	1.869	10	0.67
26	7	2006	492	2	30.4	9.350	20.0	1.870	10	0.66
27	7	2006	493	2	30.4	9.354	20.0	1.871	10	0.66
28	7	2006	494	2	30.4	9.359	20.0	1.872	10	0.66
29	7	2006	495	2	30.4	9.364	20.0	1.873	10	0.66
30	7	2006	496	2	30.4	9.369	20.0	1.874	10	0.66
31	7	2006	497	2	30.4	9.373	20.0	1.875	10	0.66
1	8	2006	498	2	30.4	9.373	20.0	1.875	10	0.66



Daily ----------

Crop development and production

Time Aggregate
● Day
○ 10-day
○ Month
○ Year

Range
From 22 March 2098
To 20 January 2099

Simulation run .... 94 out of 94

Select Output File
● Crop development and production
○ Profile/Root zone .... soil water conter
○ Soil water balance
○ Climate input data
○ Compartments .... soil water conter
○ Net irrigation requirement

Day	Month	Year	DAP	Stage	WP	Biomass	HI	Yield Part	Brelative	WPet
					g/m2	ton/ha	%	ton/ha	%	kg/m3
11	1	2099	296	2	42.5	10.322	20.0	2.064	12	0.98
12	1	2099	297	2	42.5	10.326	20.0	2.065	12	0.98
13	1	2099	298	2	42.5	10.329	20.0	2.066	12	0.97
14	1	2099	299	2	42.5	10.332	20.0	2.066	12	0.97
15	1	2099	300	2	42.5	10.335	20.0	2.067	12	0.97
16	1	2099	301	2	42.5	10.338	20.0	2.068	12	0.96
17	1	2099	302	2	42.5	10.340	20.0	2.068	12	0.96
18	1	2099	303	2	42.5	10.342	20.0	2.068	12	0.96
19	1	2099	304	2	42.5	10.343	20.0	2.069	12	0.95
20	1	2099	305	2	42.5	10.343	20.0	2.069	12	0.95

5.2.2 Climate Change Impact on Sugarcane Yields

The impact of climate change on yield which results for each combination of (i) crop (ii) (climate) and CO2 are given here. The result discussed here shows the impact of climate change on crop yields assuming that the irrigation application remains the same as under current conditions.

Climate change impact on sugarcane yield was analyzed by comparing baseline yield and future yield for the 2020s, 2040s ,2060s and 2080s.In the 2020s for both scenario, the yield show increasing in about 2.80ton/ha and 3.12ton/ha for 8.5rcp respectively. In period of 2040s the same trained continue that increases in 4.5rcp by 2.96 ton/ha and, For 8.5rcp up to 3.13 ton/ha is observed. In 2060s for both there is Increase in yield both for 4.5rcp and 8.5rcp by 3.11ton/ha and3.22 ton/ha respectively. In the 2080s increasing of yield is there for both scenario having the value of 3.02ton/ha and 3.32ton/ha respectively.

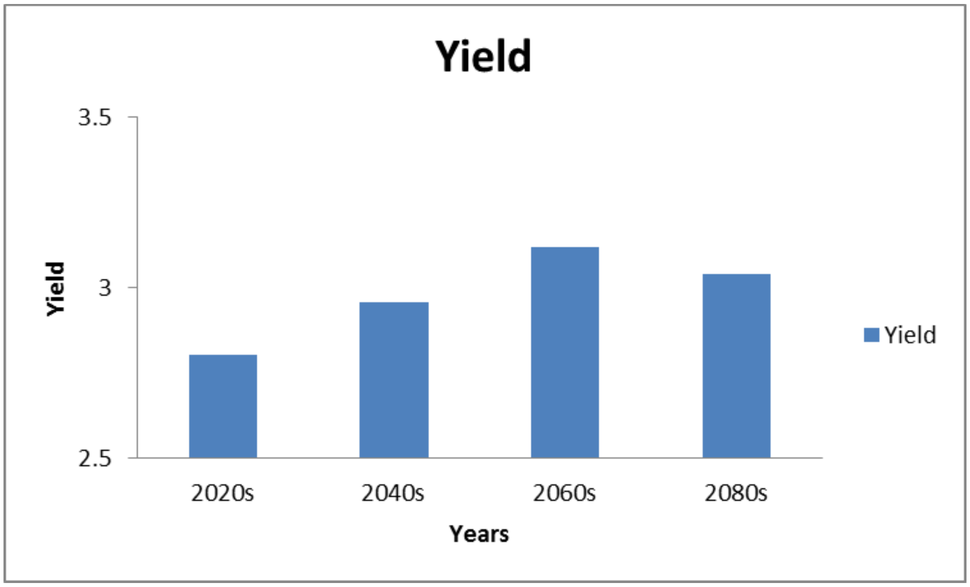


Figure 11: change in mean of yield for 4.5rcp scenario

Table 7: Change in mean of yield for 4.5rcp

Yiled	years
2.80375	2020s
2.9555	2040s
3.118565	2060s
3.040609	2080s

% change
0.3
1.8
7.02
4.82

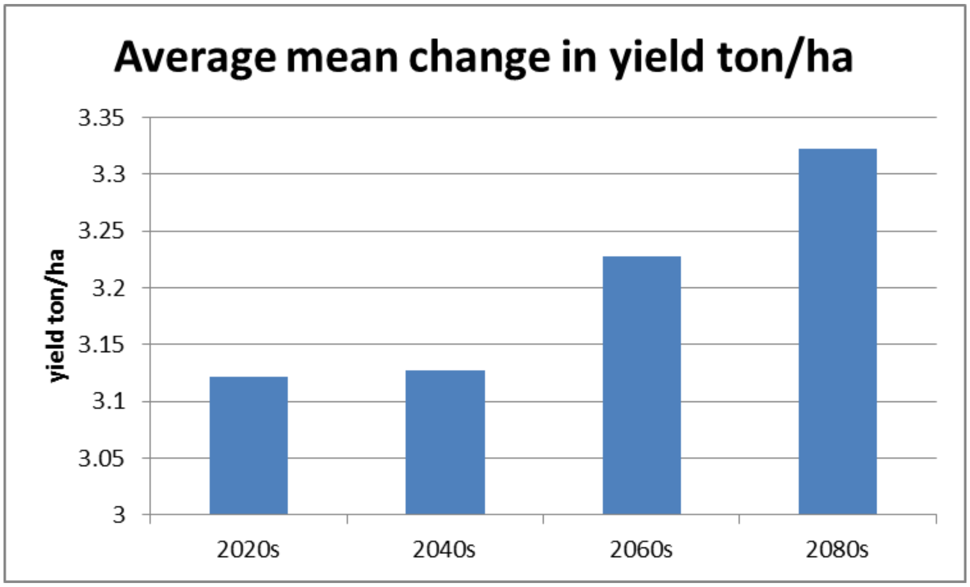


Figure 12: Change in mean yield for 8.5 rcp

Table 8: change in mean yield for 8.5 rcp

year	Yield	% change
2020s	3.121217	6.2
2040s	3.127472	7.84
2060s	3.22787	11.03
2080s	3.32212	14.48

5.2.3 Climate Change Impact on Sugarcane Biomass

Climate change impact on sugarcane biomass was analyzed by comparing baseline biomass and future biomass yield for the 2020s, 2040s ,2060s and 2080s. In the 2020s for the 4.5 rcp scenario, the biomass show increasing in about 14.01ton/ha and for 8.5rcp scenarios by 15.60ton/ha. In period of 2040s the same trained continue that in 4.5rcp by 14.77ton/ha and, for 8.5rcp up to 15.3 ton/ha is observed. In 2060s also for both scenario there is Increase in biomass production that, for 4.5rcp 15.56ton/ha and 8.5rcp by and16.13 ton/ha respectively. In the 2080s increasing of biomass production is there for both scenario having the value of 15.3ton/ha and 16.61ton/ha respectively.

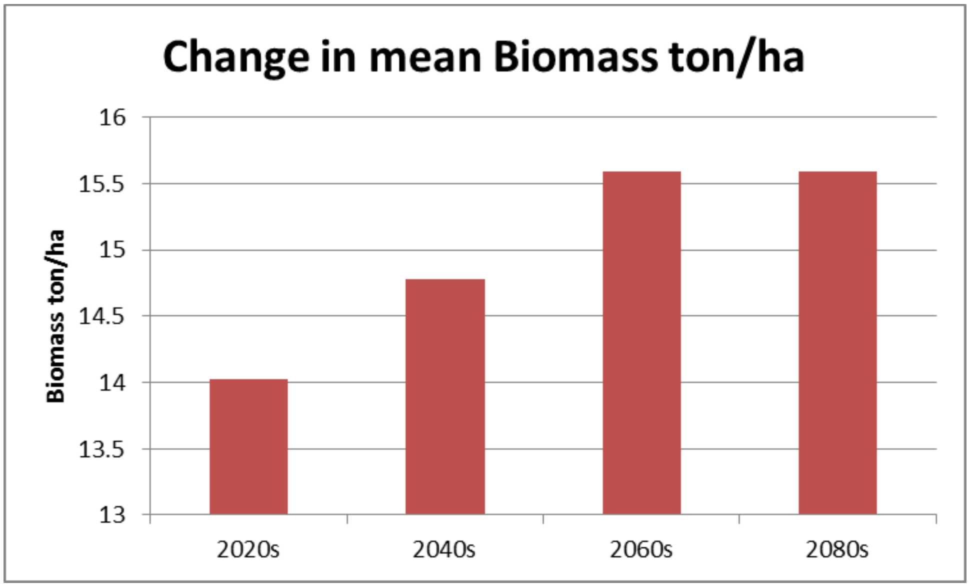


Figure 13: change in mean biomass production for 4.5rcp

Table 9: change in mean biomass production for 4.5rcp

Biomass	Year
14.01913	2020s
14.77742	2040s
15.59283	2060s
15.283	2080s

% change
1.01
0.68
6.28
6.28

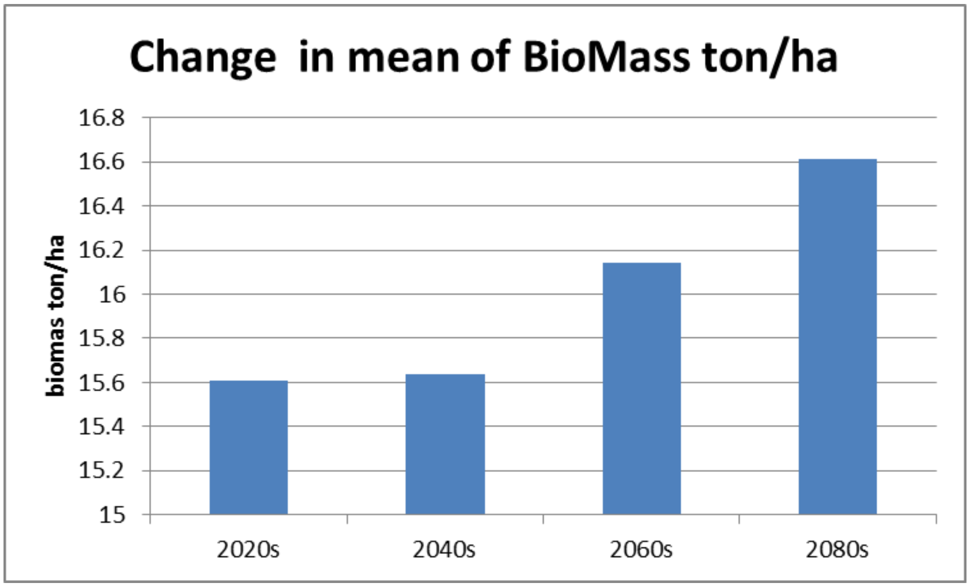


Figure 14: change in mean biomass production for 8.5rcp

Table 10: change in mean biomass production for 8.5rcp

year	BioMass	% change
2020s	15.60665	6.33
2040s	15.63792	6.54
2060s	16.13939	9.95
2080s	16.61016	13.22

5.2.3 Climate Change Impact on Sugarcane Evapotranspiration

Evapotranspiration rates are controlled by several variables including the available water and energy. A temperature increase leads to higher energy available for evapotranspiration. Although a warmer atmosphere can hold more water, the actual changes in evapotranspiration will depend on the humidity levels and the wind patterns. The observed evapotranspiration is compared with the one Aquacrop produced by using downscaled climate data (Tmax and Tmin) and location (altitude, latitude) data of wonjishoa for future time period. In the 2020s for the 4.5 rcp scenario, the Eto show increasing in about 121.13mm and for 8.5rcp scenarios by 293.08mm.. In period of 2040s the same trained continue that increases in 4.5rcp by 168.24mm and, For 8.5rcp an increase up to 390.08mm is observed. In 2060s for both scenario there is an Increase Eto by 190.3mm for 4.5rcp and 448.3mm 8.5rcprespectively. In the 2080s increasing of Eto is there for both scenario having the value of 228.44 mm and 461.3mm respectively.

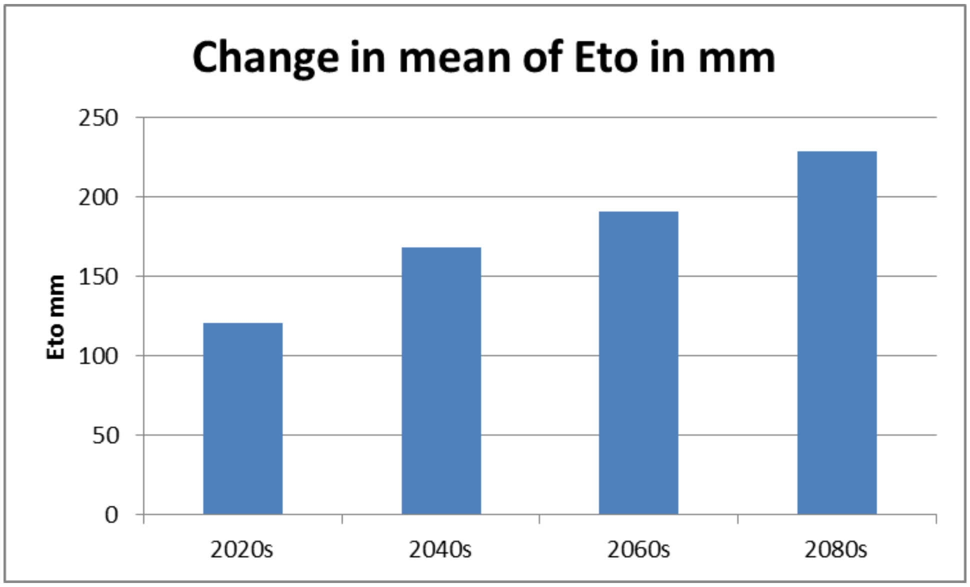


Figure 15: average mean change of Eto for 4,5rcp scenario

Table 11: mean change of Eto for 4.5 rcp

year	Eto	%change
2020s	121.1304	8.4
2040s	168.3478	11.65
2060s	190.5652	13.22
2080s	228.44	15.85

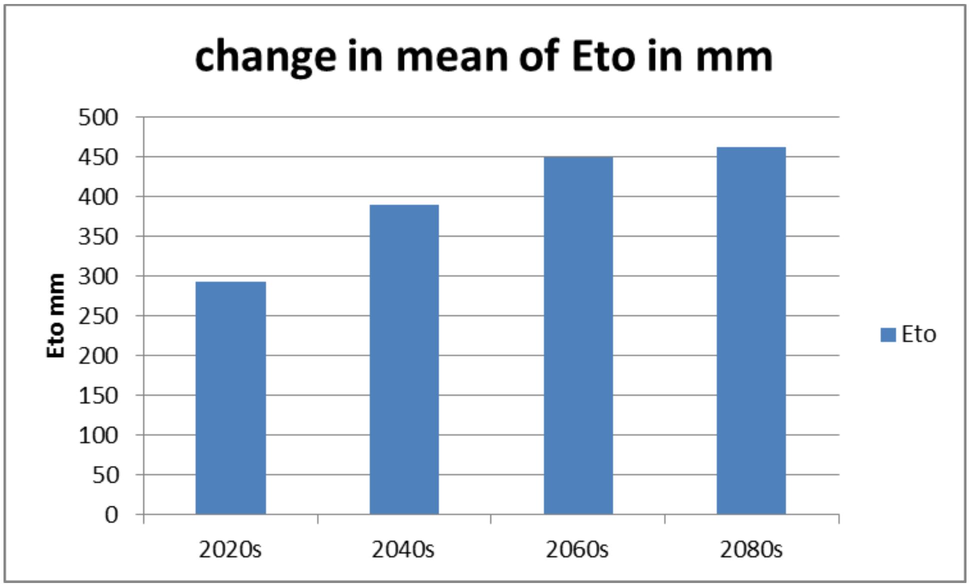


Figure 16: Average mean change of Eto for 8.5 rcp scenario

Table 12: Average mean change of Eto for 8.5 rcp scenario

years	Eto	%change
2020s	293.5417	20.34
2040s	390.0833	20.14
2060s	448.913	23.59
2080s	461.6957	24.36

5.2.4 Climate Change Impact on Sugarcane Irrigation Requirement

For the irrigated sugarcane crop, the climate impact on irrigation amounts was assessed, assuming same future yields. To meet that yield the assigned water for production give us the clue about irrigation requirement. The difference in irrigation application between the base line scenario and future with the same yield present here. In the 2020s for the 4.5 rcp scenario, the irrigation requirement show any decreasing or increasing trends for successive four benchmarks. For 8.5rcp scenarios irrigation requirement show decreasing starting from 2060s. In 2060s requirement decreases by 5.22mm and in the 2080s decreasing of irrigation requirement reach value of 62.4mm.

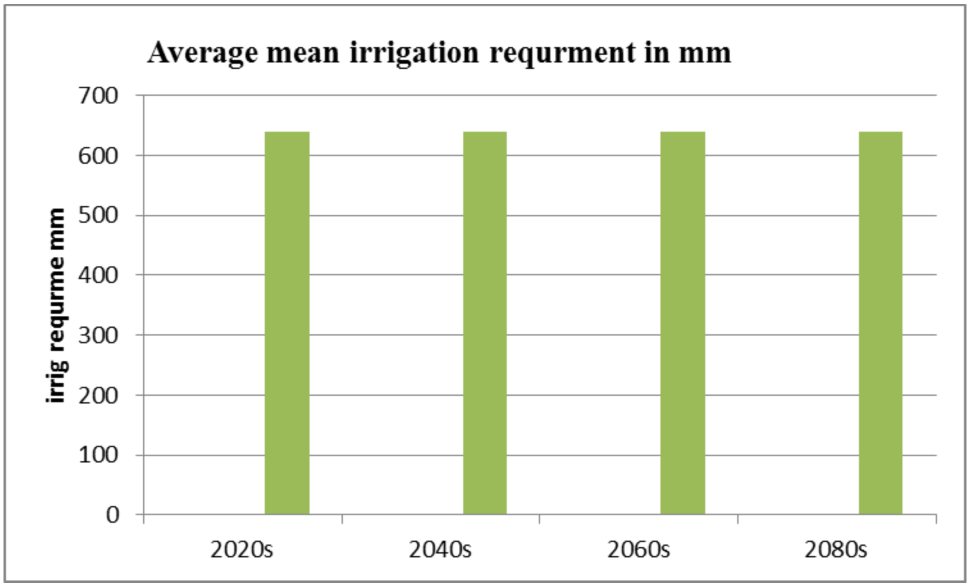


Figure 17: mean irrigation requirement for 4.5rcp

Table 13: Irrigation Requirement for 4.5 rcp

Irrg Requ	years	% change
640	2020s	0
640	2040s	0
640	2060s	0
640	2080s	0

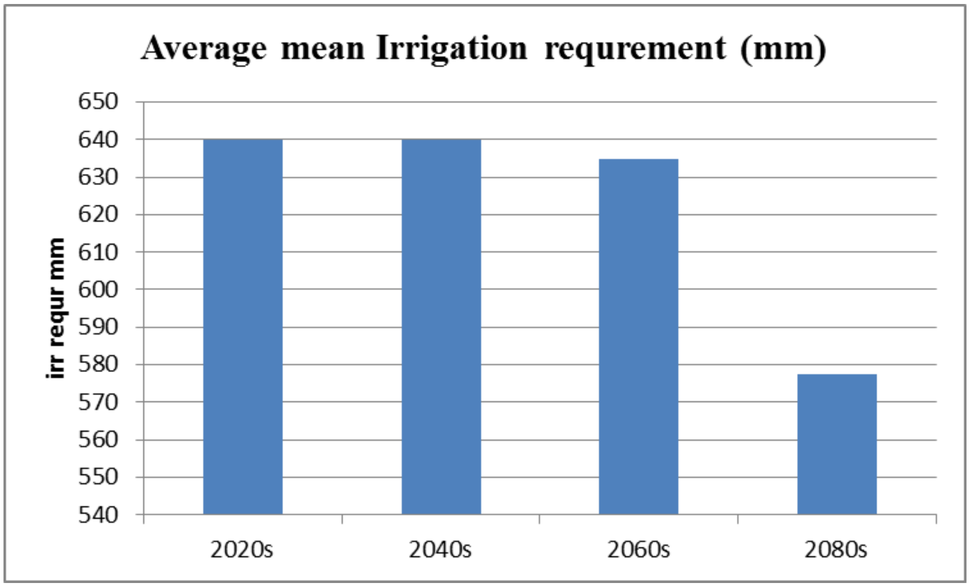


Figure 18: mean irrigation requirement for 8.5rcp

Table 14: irrigation requirement for 8.5rcp

year	Irri requ	% change
2020s	640	0
2040s	640	0
2060s	634.7826	0.816
2080s	577.6	9.75

5.2.5 Uncertainties in the Study

There are various sources of uncertainties climate change impact assessment works. The uncertainties for this study results from GCM outputs and Problem related to Aquacrop model development. Unavoidably, the approach developed in this study which has linked climate scenarios and crop modeling has limitations. This study does not take into account the possibility of future change in daily rainfall distribution within the seasons, or changes in the frequency of extreme events such as droughts, heat waves or cloudiness, which could substantially change the results discussed here

As here used multiple GCMs to help address uncertainty, the same approach could be extended by using multiple crop models in studies of climate change impacts on crop yield to further address uncertainties

Climate scenarios have many uncertainties including that, in the future projections of climate generally stem from uncertainties in defining the factors (e.g. population growth, economic growth and development, energy use, control measures, transfer of clean technology to developing countries) that affect future emissions scenarios. Converting these emissions to atmospheric concentrations of the relevant greenhouse gases is also problematic.

Any or all of the above uncertainties may cause the results to deviate from reality. Hence great care should be taken in interpreting the result by taking into account all these uncertainties.

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In this study, the impact of climate change on the crop yield and irrigation requirement is assessed based on projected climate conditions by using downscaled RCM out puts of CORDEX for both medium and high (4.5rcp and 8.5rcp) scenarios with AQUACROP model.

For WonjiShoa plantation estate, the average annual minimum temperature in 2020s will be increased by 1.35°C and 1.59 °C for 4.5rcp and 8.5rcp scenario respectively. For the 2040s periods the average annual minimum temperature will be increased by 1.79°C and 2.7°C for 4.5rcp and 8.5rcp scenario respectively. For the 2060s periods the average annual minimum temperature will be increased by 2.59°C and 3.63°C for 4.5rcp and 8.5rcp scenario respectively. For the late 21 century the average annual minimum temperature will be increased by 2.79°C and 4.09°C for 4.5rcp and 8.5rcp scenario respectively.

For WonjiShoa plantation estate, the overall analysis (2011-2099) of maximum temperature showed that there may be increasing trends in both scenarios (4.5rcp and 8.5rcp). The average annual maximum temperature in 2020s will be increased by 1.21°C and 1.16°C for 4.5rcp and 8.5rcp scenario respectively. For the 2040s periods the average annual maximum temperature will be increased by 1.48°C and 1.93°C for 4.5rcp and 8.5rcp scenario respectively. For the 2060s periods the average annual maximum temperature will be increased by 1.52°Cand 2.98°C for 4.5rcp and 8.5rcp scenario respectively. For the 2080s periods the average annual maximum temperature will be increased by 1.97°Cand 4.17°C for 4.5rcp and 8.5rcp scenario respectively.

The precipitation projection exhibited an increase in average mean precipitation in periods (2020s, 2040s ,2060s and 2080s). The overall effect in 2020s may be an increase of average annual precipitation by 6.85mm in the 4.5rcp scenario and 1.57mm in the 8.5rcp scenario. The overall effect in 2040s may be an increase of average annual precipitation by 6.6mm in the 4.5 scenario and 3.4mm in the 8.5 scenario. In 2060s the

4.5rcp and 8.5rcp scenarios showed an increase in average annual precipitation amount by 8.83mm and 11.07mm respectively. In 2080s the overall effect may be an increase of average annual precipitation by 9.88mm in the 4.5 scenario and 18.34mm in the 8.5 scenario.

The result from the downscaled annual temperature and precipitation changes showed that the climate in the WonjiShoa area will generally become warmer and wetter in each scenario. The possible range of climate change conditions were translated to link with Aquacrop to predict impact analysis.

Sensitivity analysis of the AQUACROP model was within Model calibration has been performed by manual calibration In all the gauged stations $R2$ values greater than 0.7 and ENS values greater than 0.5 has been obtained during calibration and validation period. Based on these results the model was used to assess the impact of climate change on the yield and irrigation requirement of the study area.

Climate change impact on sugarcane yield was analyzed by comparing baseline yield and future yield for the 2020s, 2040s ,2060s and 2080s. In the 2020s for both scenario, the yield show increasing in about 2.80ton/ha and 3.12ton/ha for 8.5rcp respectively. In period of 2040s the same trained continue that increases in 4.5rcp by 2.96 ton/ha and, For 8.5rcp up to 3.13 ton/ha is observed. In 2060s for both there is Increase in yield both for 4.5rcp and 8.5rcp by 3.11ton/ha and3.22 ton/ha respectively. In the 2080s increasing of yield is there for both scenario having the value of 3.02ton/ha and 3.32ton/ha respectively.

In the 2020s for the 4.5 rcp scenario, the biomass show increasing in about 14.01ton/ha and by 15.60ton/ha for 8.5rcp. In period of 2040s the same trained continue that in 4.5rcp by 14.77ton/ha and, for 8.5rcp up to 15.3 ton/ha is observed. In 2060s also for both scenario there is Increase in biomass production that, for 4.5rcp 15.56ton/ha and 8.5rcp by and16.13 ton/ha respectively. In the 2080s increasing of biomass production is there for both scenario having the value of 15.3ton/ha and 16.61ton/ha respectively.

In the 2020s for the 4.5 rcp scenario, the Eto show increasing in about 121.13mm and for 8.5rcp scenarios by 293.08mm.. In period of 2040s the same trained continue that increases in 4.5rcp by 168.24mm and, For 8.5rcp an increase up to 390.08mm is observed. In 2060s for both scenario there is an increase Eto by 190.3mm and 448.3mm for 4.5rcp and 8.5rcprespectively. In the 2080s increasing of Eto is there for both scenario having the value of 228.44 mm and 461.3mm .

In the 2020s for the 4.5 rcp scenario, the irrigation requirement show any decreasing or increasing trends for successive four benchmarks. For 8.5rcp scenarios, for two benchmarks (2020s-2040s) there is no change in irrigation requirement. For 8.srcp irrigation requirement show decreasing starting from 2060s. In 2060s requirement decreases by 5.22mm and in the 2080s decreasing of irrigation requirement reach value of 62.4mm.

6.2 Recommendation

The focus of this study was to assess and investigate the impact of climate changes on crop yield and irrigation requirement in Wonji Shoa Plantation Estate, the study showed that the impact of climate change in sugarcane yield is positive. There is no indication of adverse impact in yield of the plantation. These show that there are some crops which are not affected by climate change that it can be taken as starting point and studies must be done to take advantage of climate change in other crops.

To increase water production in the area the Estate must take different mechanisms, since Awash river show high reduction currently. Water productivity can be achieved by allowing high depletion in the root zone which allow as to reduce irrigation events with out decreasing crop productivity.

In addition to fluctuations on temperature and precipitation, population growth are among current trends Estate. The shallow ground water at the place is also one another problem at the site so, further study connecting the climate change, ground water and production may held.

In this study more than the impact of climate change on the crop yield and on the water requirement, the impact of ground water is observed which show immediate action must be taken.

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ANNEXES

Appendix A: Meteorological variables used for modeling work

Summary of Average Monthly Meteorological Variables from 1990-2016 used for modeling.

1 Monthly Minimum Temperature

year	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1990	14.8	9.2	10.2	14.0	14.6	15.6	9.4	13.2	12.4	15.6	14.4	13.6
1991	12.0	6.6	15.2	14.8	15.0	15.6	12.8	10.2	9.6	17.6	15.0	13.8
1992	10.4	5.2	14.4	13.8	15.4	17.0	7.4	11.4	10.2	17.0	15.0	11.2
1993	14.6	13.4	11.8	17.0	15.6	16.0	10.4	8.6	12.2	14.6	10.8	7.8
1994	13.4	13.4	9.2	12.6	14.8	16.2	9.8	9.2	10.4	15.0	4.6	7.2
1995	15.6	8.8	8.0	13.0	13.8	11.2	13.4	6.6	14.8	12.4	6.4	9.2
1996	14.2	12.2	9.4	14.0	14.6	12.6	17.0	6.4	16.2	13.0	7.4	10.4
1997	13.8	13.6	12.6	10.8	14.2	11.5	16.8	8.8	15.5	16.8	8.2	12.6
1998	12.2	9.8	10.6	16.2	13.8	16.4	13.0	8.2	13.0	16.0	5.4	14.2
1999	16.9	13.6	6.6	15.6	12.8	17.2	8.6	14.8	11.0	15.6	3.0	11.6
2000	17.0	15.0	7.2	17.2	13.8	15.0	13.0	15.0	14.4	15.4	2.8	16.2
2001	15.4	16.4	10.8	15.0	12.4	14.5	10.0	15.0	14.4	15.6	4.6	16.4
2002	16.6	9.4	7.4	13.2	15.0	16.4	16.0	11.2	13.0	14.2	7.2	13.6
2003	16.2	14.2	9.2	16.0	12.0	17.0	16.0	8.4	5.4	13.8	13.7	16.6
2004	16.8	13.0	11.0	15.0	15.6	17.6	13.0	12.4	4.4	13.6	13.4	17.6
2005	14.5	13.1	8.8	16.8	17.0	15.4	16.0	16.0	5.4	12.0	15.0	17.2
2006	12.0	12.5	8.4	16.8	15.0	14.5	14.0	16.6	10.4	12.0	15.6	17.4
2007	11.0	13.0	9.0	13.4	17.6	16.6	16.4	10.2	10.0	8.4	14.2	17.2
2008	15.2	8.0	9.0	16.8	15.2	16.8	15.8	15.4	11.6	9.2	15.2	17.2
2009	15.8	6.8	6.0	15.2	15.4	13.8	15.0	16.8	8.8	8.8	14.8	16.2
2010	17.2	6.8	5.4	17.2	16.0	9.8	12.4	16.8	13.2	9.8	15.4	16.0
2011	15.2	5.8	8.0	16.0	14.0	12.6	10.0	10.4	12.8	9.4	15.4	15.2
2012	15.8	12.2	15.2	15.0	14.2	17.2	11.6	9.8	15.6	11.0	14.4	13.6
2013	15.2	15.6	15.6	13.4	16.2	15.8	14.4	5.2	14.6	7.6	13.6	15.8
2014	14.8	14.0	13.4	13.6	13.8	15.2	14.4	5.4	15.4	5.6	13.6	15.6
2015	15.0	16.0	11	15	15.6	17.6	13	12.4	4.4	13.6	13.4	17.6
2016	13.0	16.0	8.8	16.8	17	15.4	16	16	5.4	12	15	17.2
Average	14.6	11.6	10.1	15.0	14.8	15.2	13.2	11.5	11.3	12.8	11.4	14.4

2 Monthly Maximum Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	26.0	25.6	27.0	27.6	24.4	29.4	22.0	27.6	25.2	25.6	24.0	27.4
1991	25.8	28.0	27.0	26.8	27.6	24.6	24.6	27.0	27.4	26.8	24.8	27.4
1992	29.4	25.2	27.2	26.8	29.6	23.2	26.6	29.2	28.4	27.4	23.4	28.0
1993	28.5	26.8	26.0	27.6	25.8	23.8	23.8	28.2	27.0	26.8	19.6	28.2
1994	28.0	29.2	26.6	28.4	25.6	26.6	23.8	29.6	28.2	25.2	25.4	28.2
1995	25.2	25.4	27.4	27.8	25.2	24.2	22.0	28.2	26.6	24.6	26.2	27.4
1996	26.8	22.6	28.4	26.2	26.8	26.0	22.6	29.0	26.0	25.2	25.6	28.8
1997	28.4	26.8	30.0	26.6	26.8	23.0	23.6	28.8	24.8	28.8	26.8	28.8
1998	27.0	28.8	27.0	26.8	25.2	25.8	27.4	27.6	24.6	29.4	25.0	27.6
1999	26.4	27.6	25.0	27.2	18.2	27.0	25.8	27.8	26.6	27.6	24.8	29.4
2000	26.4	26.6	21.6	26.4	20.0	28.6	24.4	28.2	27.6	31.2	25.2	28.8
2001	27.2	23.0	23.8	26.2	23.4	26.4	23.4	29.0	25.6	29.8	28.2	27.6
2002	27.0	18.4	27.4	25.6	24.8	24.2	23.2	28.8	27.4	30.0	27.2	27.6
2003	28.0	18.2	27.0	25.4	23.6	23.4	26.4	22.4	23.2	30.8	26.4	26.8
2004	29.0	18.8	28.4	25.2	24.4	27.0	27.2	22.0	22.0	28.8	27.6	25.4
2005	30.6	20.4	27.0	28.8	25.8	25.6	30.2	23.0	26.0	28.6	28.0	26.6
2006	28.8	23.0	27.6	29.8	27.2	26.0	28.0	27.4	27.0	27.0	27.6	25.6
2007	27.0	25.0	29.2	29.4	27.0	26.2	25.8	25.8	27.4	26.6	25.6	24.6
2008	22.0	26.4	28.4	27.0	28.8	24.4	26.4	28.2	29.8	28.0	26.4	22.6
2009	28.0	26.6	24.5	25.8	26.8	27.2	27.6	26.0	27.6	26.0	28.0	25.2
2010	27.6	25.6	25.0	27.4	25.0	26.4	28.4	25.6	26.6	24.4	28.6	25.4
2011	23.4	25.4	25.1	26.8	25.8	26.6	27.6	28.2	29.2	25.6	28.6	29.4
2012	21.0	24.8	27.0	25.8	26.8	27.8	28.4	27.8	30.6	24.8	28.2	28.6
2013	24.0	30.4	28.4	25.0	26.0	26.6	28.8	28.0	29.6	29.2	28.0	25.8
2014	27.6	28.4	27.0	24.8	26.4	27.2	28.4	26.2	25.6	28.8	27.2	28.4
2015	28.4	30.0	27.0	24.8	26.8	26.0	28.2	26.6	22.4	28.4	24.2	28.2
2016	25.0	31.0	26.4	25.8	27.2	25.4	28.2	27.4	23.8	28.6	26.4	26.0
Average	26.8	25.5	26.8	26.7	25.6	25.9	26.0	27.2	26.5	27.6	26.2	27.2

3 monthly precipitation mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	0	118.8	135.6	109.7	18.3	8.1	199.7	259.1	102.5	3.6	0	0
1991	0	32.9	188.5	8.9	30.2	82.9	186	215.8	85.7	7.5	0	0
1992	35.2	4.8	3.5	34.5	13.8	107.3	223.4	251.5	99.2	39.8	24.9	9.9
1993	4.2	68.4	0	138.8	80.8	61.5	323	106.6	89.7	49.5	0	2.8
1994	0	0	13.1	27.3	28.5	44.7	171.8	144.2	116	18.1	17.2	56.8
1995	0	53.5	103.8	89.2	31.7	93	153.4	181.7	108	7.1	0	8.6
1996	8.1	0	88.3	50.5	109.1	128.3	175.2	90.2	0	0	2.1	0
1997	19	0	34.9	27.3	1.3	133.7	218.3	140.5	41.8	69.1	8.2	0
1998	36.2	38.3	47	17.4	33.5	48.8	179.5	286.1	88.7	123.2	0	0
1999	9	0	51.6	0.6	4.6	58.3	202.8	183.2	87.3	148.25	0	0
2000	0	0	0	44.2	79.6	62.4	221.3	174.8	75.8	72	28.5	2.7
2001	0	12.1	87.7	21.2	95	90.8	236.7	154	53.4	10	0	7.6
2002	6.5	7	23.6	33.5	46.1	25.4	86.4	182.5	50.5	0	0	44.6
2003	32.3	62.8	138.8	40.9	9.8	84.5	186.4	157.1	95.5	0	0.8	69.9
2004	35.5	0	72	88	5.5	48.9	143.9	200.4	79.7	39.3	12.7	38.3
2005	45.1	1	145.4	50.1	64.9	62.1	118.1	225.8	103.9	9	10.6	0
2006	4.1	43.4	90.8	84	39.1	86.6	173.5	209.3	64.2	9.2	0	28.2
2007	95	8.8	78.8	61.5	116.2	57.3	181.5	170.4	128.4	36	4.7	0
2008	1.8	1.1	0	39.9	76	84.3	313.6	252.5	88	52	117.1	0
2009	47.5	0	21.9	26.9	38.2	36.7	76.1	139.9	22.4	108.1	0.5	37.3
2010	0	91	65.8	65.8	69.2	123.81	185.9	173.6	108.5	0	1.8	1.8
2011	0	0	34.1	3.6	35.5	86.4	145.5	118.9	206.5	0	54.5	0
2012	0	0	18.7	33.6	76.5	11.1	487.9	231.6	126.3	2	0	0
2013	4.5	0	65.5	32	57	0	491.1	98.5	122.6	28.2	7.9	0
2014	0	0	120.8	0	47.4	0	151.5	139.1	124.9	70.5	0	0
2015	0	0	20	0	177.6	23	116.3	140.7	80	0	32.4	2.4
2016	6.7	0	15.4	0	117.1	66.7	361.6	108.3	125.1	0	0	0
Average	14.47037	20.14444	61.68889	41.82963	55.64815	63.57815	211.4963	175.4185	91.65185	33.42407	11.9963	11.51481

Aquacrop model result for 4.5rcp (a)

Year1	Rain	ETo	GD	CO2	Irri	Infilt	Runoff	BioMass	Brelative	HI	Yield	WPet
	mm	mm	−C.day	ppm	mm	mm	mm	ton/ha	%	%	ton/ha	kg/m3
2005	562	1967	4768	380.85	640	848	354	13.91	14	20	2.782	0.83
2006	728	2041	4767	382.83	640	985	382	13.114	13	20	2.623	0.83
2007	1070	1935	4775	384.68	640	1157	553	13.457	14	20	2.691	0.85
2008	1020	1943	4771	386.48	640	1074	586	12.597	13	20	2.519	0.76
2009	613	1886	4778	388.61	640	888	365	14.919	15	20	2.984	0.96
2010	528	1867	4770	390.74	640	835	333	14.347	15	20	2.869	0.86
2011	584	1968	4773	392.73	640	848	376	14.245	15	20	2.849	0.92
2012	603	2000	4775	395.15	640	871	373	21.198	22	20	4.24	0.98
2013	768	934	4768	397.51	640	1010	398	12.967	13	20	2.593	0.81
2014	926	2145	4777	399.27	640	1105	461	12.744	13	20	2.549	0.86
2015	895	151	4773	401	640	1050	485	14.352	15	20	2.87	0.84
2016	1231	1984	4770	403	640	1228	642	12.437	13	20	2.487	0.8
2017	1069	1962	4774	405.5	640	1200	509	11.488	12	20	2.298	0.78
2018	772	945	4768	408	640	985	427	12.785	13	20	2.557	0.75
2019	930	1174	4772	410	640	1097	473	17.799	18	20	3.56	0.95
2020	797	2039	4770	412	640	960	477	13.466	14	20	2.693	0.91
2021	856	952	4770	414.5	640	1011	484	14.26	14	20	2.852	0.91
2022	986	977	4767	417	640	1111	515	13.721	14	20	2.744	0.94
2023	1125	3071	4771	419	640	1225	540	12.279	12	20	2.456	0.77
2024	962	2155	4773	421.5	640	1041	560	11.766	12	20	2.353	0.82
2025	565	1906	4768	424	640	862	343	13.897	14	20	2.779	0.92
2026	817	1910	4775	426.5	640	1030	427	14.576	15	20	2.915	0.84
2027	585	1823	4770	429	640	865	360	13.271	13	20	2.654	0.86
2028	555	1894	4776	431.5	640	781	414	16.864	17	20	3.373	0.96
2029	714	982	4768	434	640	973	381	14.834	15	20	2.967	0.92
2030	767	960	4777	436.5	640	941	467	14.787	15	20	2.957	1.01
2031	791	1693	4770	439	640	924	507	13.609	14	20	2.722	0.89
2032	681	717	4771	441.5	640	921	400	13.104	14	20	2.621	0.85
2033	532	1871	4777	444	640	828	344	13.514	13	20	2.703	0.86
2034	705	862	4767	446.5	640	910	435	13.465	13	20	2.693	0.92
2035	1058	942	4769	449	640	1133	565	13.72	14	20	2.744	0.96
2036	554	771	4775	451.5	640	842	352	15.072	15	20	3.014	0.94
2037	620	1841	4770	454.5	640	887	373	17.195	17	20	3.439	0.95
2038	509	1768	4775	457	640	820	329	15.182	15	20	3.036	0.9
2039	655	1849	4773	459.5	640	871	424	14.87	15	20	2.974	0.94
2040	827	1909	4767	462	640	1054	413	13.168	13	20	2.634	0.89
2041	1057	1836	4771	464.5	640	1213	484	12.464	12	20	2.493	0.82
2042	736	1737	4770	467.5	640	968	408	13.138	13	20	2.628	0.9
2043	801	213	4766	470	640	976	465	13.52	13	20	2.704	0.89
2044	709	1778	4777	472.5	640	930	418	14.226	14	20	2.845	0.87
2045	872	2169	4767	475	640	1030	482	15.111	15	20	3.022	0.98
2046	760	2233	4774	477.5	640	990	409	12.681	13	20	2.536	0.88
2047	486	1828	4774	480	640	820	306	25.329	25	20	5.066	1.06
2048	563	1783	4769	482.5	640	833	370	15.145	15	20	3.029	1.03
2049	564	1778	4771	485.5	640	833	371	15.545	16	20	3.109	1.04
2050	405	1739	4774	488	640	755	290	13.914	14	20	2.783	0.94
2051	680	1708	4769	490.5	640	900	420	14.414	15	20	2.883	1.08
2052	685	1779	4775	493	640	922	403	16.651	17	20	3.33	0.96
2053	479	1792	4775	495	640	777	342	16.298	16	20	3.26	1.07

Aquacrop model result for 4.5rcp (b)

2054	1060	998	4773	497	640	1114	586	13.561	13	20	2.712	0.95
2055	453	824	4771	499.5	640	794	299	14.568	14	20	2.914	0.88
2056	501	1795	4776	502	640	799	342	14.35	14	20	2.87	1.02
2057	346	1757	4773	504	640	698	287	15.91	16	20	3.182	1.06
2058	791	1795	4767	506	640	1007	424	15.472	15	20	3.094	0.96
2059	603	1789	4774	508	640	877	366	14.775	15	20	2.955	0.97
2060	607	1788	4768	510	640	897	351	14.326	14	20	2.865	0.9
2061	505	1690	4778	512	640	806	339	13.462	14	20	2.692	0.94
2062	912	1314	4774	513.5	640	1020	532	12.998	13	20	2.6	0.97
2063	554	994	4779	515	640	861	333	25.749	25	20	5.15	1.06
2064	435	1783	4774	517	640	763	312	14.616	15	20	2.923	1.01
2065	492	1775	4769	518.5	640	786	346	20.65	20	20	4.13	0.99
2066	585	1830	4772	519.5	640	868	357	14.363	14	20	2.873	0.94
2067	618	1729	4776	521	640	853	405	14.377	15	20	2.875	0.99
2068	1489	1642	4774	522.5	640	1408	721	9.625	10	20	1.925	0.78
2069	429	1779	4774	523.5	640	745	324	18.151	18	20	3.63	1.09
2070	698	1841	4771	524.5	640	851	488	22.904	22	20	4.581	1.16
2071	854	1757	4767	526	640	990	504	13.481	13	20	2.696	0.95
2072	836	1696	4778	527	640	1004	472	14.599	14	20	2.92	0.98
2073	544	675	4773	527.5	640	841	343	12.994	13	20	2.599	0.9
2074	418	1725	4770	528.5	640	739	319	14.382	15	20	2.876	1.02
2075	823	1800	4769	529.5	640	990	473	17.024	17	20	3.405	1.07
2076	887	1853	4777	530	640	1052	474	13.233	13	20	2.647	0.88
2077	504	1730	4767	530.5	640	838	306	16.023	16	20	3.205	0.9
2078	518	1688	4779	531	640	826	331	13.888	14	20	2.778	1
2079	696	1593	4767	531	640	915	421	17.672	18	20	3.534	0.97
2080	513	1593	4774	531	640	803	350	16.756	18	20	3.351	1.12
2081	431	1793	4768	531	640	746	325	18.485	18	20	3.697	1.09
2082	981	976	4773	531.5	640	1091	530	13.917	14	20	2.783	0.98
2083	827	931	4772	532	640	988	480	15.297	15	20	3.059	0.94
2084	551	1739	4778	532	640	837	354	16.113	16	20	3.223	0.99
2085	371	1666	4770	532	640	710	301	16.119	17	20	3.224	1.08
2086	675	1758	4777	532.5	640	908	407	13.797	14	20	2.759	1
2087	403	1771	4775	533	640	735	308	15.29	15	20	3.058	1.01
2088	673	1716	4770	533	640	897	417	16.17	16	20	3.234	0.99
2089	689	1743	4767	533.5	640	943	386	14.415	14	20	2.883	0.97
2090	783	908	4774	534	640	986	437	13.548	13	20	2.71	0.93
2091	578	1675	4769	534.5	640	862	356	13.746	14	20	2.749	0.95
2092	624	720	4774	535	640	863	402	15.245	15	20	3.049	1.02
2093	630	915	4772	535	640	838	432	15.56	16	20	3.112	0.94
2094	653	720	4771	535.5	640	909	383	14.665	15	20	2.933	0.93
2095	769	1702	4777	536	640	916	493	14.586	15	20	2.917	0.98
2096	503	1791	4772	536.5	640	797	345	14.287	14	20	2.857	0.97
2097	446	1810	4774	537	640	763	323	16.261	16	20	3.252	1.04
2098	506	1771	4780	537.5	640	814	332	14.599	14	20	2.92	1

Aquacrop model result for 8.5 rcp (a)

Day1	Month1	Year1	Rain	ETo	GD	CO2	Irri	Infilt	BioMass	HI	Yield	WPet
			mm	mm	−C.day	ppm	mm	mm	ton/ha	%	ton/ha	kg/m3
22	2	2005	1445	1038	4773	380.85	640	1174	12.994	20	2.599	0.86
22	2	2006	1041	1016	4771	382.83	640	1127	14.632	20	2.926	0.88
22	2	2007	1111	909	4778	384.68	640	1170	15.064	20	3.013	0.85
22	2	2008	637	1988	4776	386.48	640	882	14.247	20	2.849	0.9
22	2	2009	646	1078	4767	388.61	640	918	20.471	20	4.094	0.98
22	2	2010	594	788	4768	390.74	640	867	15.152	20	3.03	0.88
22	2	2011	709	1126	4777	392.73	640	960	13.863	20	2.773	0.89
22	2	2012	431	1890	4770	395.15	640	765	14.635	20	2.927	0.9
22	2	2013	379	1781	4770	397.51	640	671	16.078	20	3.216	0.95
22	2	2014	780	1837	4768	400.27	640	990	19.306	20	3.861	0.97
22	2	2015	494	1884	4777	403	640	798	13.601	20	2.72	0.91
22	2	2016	579	1975	4776	405.5	640	870	14.702	20	2.94	0.92
22	2	2017	505	939	4770	408.5	640	826	16.116	20	3.223	0.92
22	2	2018	668	937	4771	411.5	640	922	13.811	20	2.762	0.89
22	2	2019	557	1860	4771	414.5	640	831	14.85	20	2.97	0.98
22	2	2020	353	1822	4775	417.5	640	706	15.26	20	3.052	0.98
22	2	2021	337	1897	4773	420.5	640	712	21.157	20	4.231	1.01
22	2	2022	652	1904	4772	423.5	640	916	15.409	20	3.082	0.97
22	2	2023	709	1887	4774	426.5	640	952	12.891	20	2.578	0.92
22	2	2024	579	1777	4768	429.5	640	859	15.022	20	3.004	0.88
22	2	2025	757	1769	4776	433	640	963	13.387	20	2.677	0.84
22	2	2026	562	1883	4774	436.5	640	832	20.76	20	4.152	1.04
22	2	2027	606	1944	4768	440	640	881	15.545	20	3.109	0.95
22	2	2028	768	1086	4772	443.5	640	964	15.001	20	3	0.93
22	2	2029	644	1021	4773	447	640	919	14.81	20	2.962	0.87
22	2	2030	658	1959	4771	450.5	640	911	16.685	20	3.337	1.01
22	2	2031	914	859	4776	454	640	1023	14.34	20	2.868	0.86
22	2	2032	588	715	4774	458	640	881	13.193	20	2.639	0.83
22	2	2033	571	279	4771	462	640	879	12.763	20	2.553	0.85
22	2	2034	752	1843	4767	466	640	977	13.986	20	2.797	0.9
22	2	2035	627	1928	4771	470	640	903	14.096	20	2.819	0.92
22	2	2036	656	1870	4767	474	640	917	13.797	20	2.759	0.94
22	2	2037	622	1830	4776	478.5	640	882	14.624	20	2.925	0.99
22	2	2038	526	1830	4773	483	640	823	13.803	20	2.761	0.95
22	2	2039	503	1820	4768	487	640	807	16.644	20	3.329	1.04
22	2	2040	535	196	4770	491.5	640	796	17.548	20	3.51	1.07
22	2	2041	671	316	4780	496.5	640	885	17.283	20	3.457	0.88
22	2	2042	656	1602	4773	501.5	640	852	14.527	20	2.905	0.93
22	2	2043	479	1823	4774	506	640	785	23.652	20	4.73	1.17
22	2	2044	625	1815	4774	510.5	640	892	15.352	20	3.07	1
22	2	2045	403	1802	4771	516	640	711	18.654	20	3.731	1.11
22	2	2046	942	1773	4773	521.5	640	986	14.061	20	2.812	1.02
22	2	2047	467	1837	4778	526.5	640	817	14.675	20	2.935	0.96
22	2	2048	712	1793	4777	532	640	901	17.031	20	3.406	1.06
22	2	2049	742	662	4773	538	640	923	12.878	20	2.576	0.96
22	2	2050	658	1756	4770	543.5	640	859	15.646	20	3.129	0.99
22	2	2051	587	1726	4771	549	640	858	13.827	20	2.765	1.03
22	2	2052	793	1663	4770	555	640	995	12.658	20	2.532	0.92
22	2	2053	807	1569	4767	561	640	1009	13.863	20	2.773	0.93
22	2	2054	868	1641	4780	567.5	640	1005	12.873	20	2.575	0.96
22	2	2055	937	1697	4776	574	640	1027	13.323	20	2.665	0.99

Aquacrop model result for 8.5 rcp (b)

22	2	2056	490	1750	4773	580	640	779	20.481	20	4.096	1.08
22	2	2057	604	1693	4770	586.5	640	887	23.23	20	4.646	1.13
22	2	2058	577	360	4771	593.5	640	824	14.761	20	2.952	1.05
22	2	2059	679	1656	4771	600.5	640	919	14.613	20	2.923	1.08
22	2	2060	311	1608	4772	607.5	640	662	16.871	20	3.374	1.16
22	2	2061	842	636	4771	614.5	640	941	12.234	20	2.447	0.92
22	2	2062	500	1579	4781	621.5	640	796	15.361	20	3.072	1.12
22	2	2063	598	1627	4775	628.5	640	858	22.319	20	4.464	1.24
22	2	2064	1045	1649	4777	635.5	640	1035	12.911	20	2.582	1.06
22	2	2065	472	1676	4779	643	640	783	16.942	20	3.388	1.12
22	2	2066	390	1636	4770	650.5	640	736	15.674	20	3.135	1.12
22	2	2067	329	1561	4766	658	580	646	26.466	20	5.293	1.16
22	2	2068	779	1538	4777	665.5	640	936	14.922	20	2.984	1.03
22	2	2069	649	1702	4775	673	640	865	16.865	20	3.373	1.14
22	2	2070	473	1647	4772	681	640	763	15.797	20	3.159	1.14
22	2	2071	688	1551	4780	689	640	920	14.44	20	2.888	0.97
22	2	2072	487	1460	4767	697	580	760	12.799	20	2.56	1
22	2	2073	375	1601	4778	705	640	721	17.976	20	3.595	1.11
22	2	2074	274	1560	4769	713	640	639	15.163	20	3.033	1.09
22	2	2075	386	1553	4778	721	640	735	18.038	20	3.608	1.19
22	2	2076	676	1503	4779	729	580	828	14.691	20	2.938	1.19
22	2	2077	727	2044	4776	737.5	580	899	15.547	20	3.109	1.1
22	2	2078	504	1581	4777	746	640	833	14.77	20	2.954	1.05
22	2	2079	616	1627	4774	754	640	817	16.628	20	3.326	1.17
22	2	2080	514	1507	4774	762.5	580	767	14.569	20	2.914	1.14
22	2	2081	480	1541	4771	771	580	753	19.693	20	3.939	1.17
22	2	2082	474	1464	4778	779.5	580	764	16.075	20	3.215	1.06
22	2	2083	604	545	4780	788	580	767	16.446	20	3.289	1.15
22	2	2084	446	1491	4778	796.5	580	689	16.835	20	3.367	1.25
22	2	2085	341	1472	4774	805.5	580	665	17.939	20	3.588	1.26
22	2	2086	558	1450	4776	814	580	811	19.067	20	3.813	1.23
22	2	2087	622	1415	4774	822.5	580	862	13.176	20	2.635	1.2
22	2	2088	411	1452	4771	831.5	580	693	14.556	20	2.911	1.21
22	2	2089	366	1481	4773	840.5	580	695	13.43	20	2.686	1.12
22	2	2090	628	1495	4776	849.5	580	761	16.168	20	3.234	1.22
22	2	2091	259	1480	4776	854	520	571	29.523	20	5.905	1.39
22	2	2092	1053	1451	4783	867.5	580	989	16.018	20	3.204	1.26
22	2	2093	311	1425	4778	872	520	612	12.158	20	2.432	1.04
22	2	2094	421	1470	4774	885.5	580	725	15.98	20	3.196	1.26
22	2	2095	486	1455	4779	890	520	728	12.415	20	2.483	1.12
22	2	2096	611	1398	4781	899	520	764	13.037	20	2.607	1.08
22	2	2097	482	1452	4767	912.5	580	725	26.098	20	5.22	1.38
22	2	2098	380	1424	4777	917	520	653	17.234	20	3.447	1.23