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IMPACT OF CLIMATE CHANGE ON ENSET PRODUCTION

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ABSTRACT: *Climate change and variability may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Future climate change is expected to have a greater and global impact on people's lives. Although Enset is among the climate resilient crops in the short term, it will be suffering from the long-term impacts. Climate variable interact with plant growth and yield. Climate change affects agriculture in a different way, including through changes in average temperatures, rainfall, and climate extremes. Climate change will affect developing countries like Ethiopia because of more dependence on rain-fed agriculture Enset is selected as "the tree against hunger" because it produces the highest energy output per time and area unit of crops grown in Ethiopia and because it remains green, saving many lives when cereals wilt before harvest or collapse due to untimely rain This aimed at investigating the possible and anticipated impacts of climate change and variability on productivity and distribution. Simulations within the horizons 2040s and 2070s showed a situation of an overall increase in temperatures that reaches 1.1, 1.2 and 1.2°C under RCP (2.6, 4.5 and 8.5) during 2040s and 1.2, 1.2 and 1.4°C under RCP (2.6, 4.5 and 8.5) scenarios during 2070s, respectively and a respective increase in rainfall of 29%, 28% and 27% under RCP (2.6, 4.5 and 8.5) during 2040s and 27%, 26% and 25% under RCP (2.6, 4.5 and 8.5) scenarios during 2070s, respectively. Therefore, the projected climate shows that the climate change and variability will have significant impacts on Enset production. Evaluation of potential climate change impacts of the future and selecting relatively more tolerant crop for adapting of climate change has no options*

KEYWORD*:* IPCC, Metane, Enset, forcing, climate change, climate variability

INTRODUCTION

Enset is an herbaceous species of flowering plant in the banana family Musaceae. The domesticated form of the plant is only cultivated in Ethiopia, where it provides the staple food for approximately 20 million people (Paul; Demissew, et al, 2019).

Climate change has emerged as one of the development challenges of the 21st century (O'Brien, et al, 2015). There is high confidence and agreement among the global scientific community that climate change poses a serious threat to current and future sustainable development. According to the forecasts, climate change-induced impacts will continue to affect people, even if anthropogenic greenhouse gasses emissions stop today (Pachauri R.K., Meyer.L.A. A, 2014).

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Agricultural productivity has been found to be affected by climate change and since such changes cause response in many human and natural systems, understanding climate variability will improve agricultural decision making and eventually productivity (Sagoe, 2006). The climate is a long-term average weather condition that either exercises directly or indirectly controls or affects agricultural production. That is to say, climate forms the major part of the physical environment in which agriculture thrives. Climate determines the choice of what plant to cultivate, how to cultivate it, the yields of crops and nature of livestock to keep. Ajadi(2011)

The climate is a long-term average weather condition that either exercises directly or indirectly controls or affects agricultural production. That is to say, climate forms the major part of the physical environment in which agriculture thrives. Climate determines the choice of what plant to cultivate, how to cultivate it, the yields of crops and nature of livestock to keep. Ajadi (2011).Agriculture sector is mainly dependent on climate situation, especially on rainfall and temperature (Anita Wreford & Adger, 2010). The sector plays a great role in the national economy and it is the mainstay for several people and main source to the livelihoods of the rural poor people. This sector facing greater challenges due to climate change and variability (Hatfield et al., 2018).

Climate variability refers to variations in the mean state and other statistics of the climate on all spatial and temporal scales beyond that of individual weather events. Climate change and variability may be due to natural internal processes or external forgings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2007).

Climate change induced-impacts refers to effects on natural and human systems due to gradual changes in climate, variations in weather and climatic elements from the average, and that of the impacts of climatic extremes. As IPCC report, climate change-induced impacts refer to impacts on human lives, livelihoods, culture, economies, ecosystems, and material resources due to hazardous climatic events over a period of time (Pachauri, et, al, 2014).

Agriculture is more fragile sector due to high dependence on rainfall, and other climate-related factors. Climate change affects agriculture in a different ways, including through changes in average temperatures, rainfall, and climate extremes (e.g., heat waves); changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods; and changes in sea level (Vuuren et al., 2011, Walthall, et al., 2012).

Most horticulturists believe that Enset production will be most affected by the severity and pace of climate change, not so much by gradual trends in climate. If change is gradual, there may be enough time for biota adjustment. Rapid climate change, however, could harm agriculture in many countries, especially those that are already suffering from rather 3 poor soil and climate conditions, because there is less time for optimum natural selection and adaption, (Kurukulasuriya& Rosenthal, 2003; Sindhu, 2011; FAO, 2016).

Enset (Ensete ventricosum (Welw.)Cheesman) is a large non-woody plant a gigantic monocarp evergreen perennial herb plant. Domesticated Enset is planted at altitudes ranging from 1,200 to 3,100 meters. However, it grows best at elevations between 2,000 and 2,750 meters. But

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Enset grows best at altitudes above 1600 masl. Most Enset-growing areas receive an annual rainfall of about 1,100 to 1,500 millimeters, the majority of which falls between March and September. The average temperature of Enset growing areas is between 10 and 21 degrees centigrade, and the relative humidity is 63 to 80 percent (Borrel et al., 2019). Thus, Enset is a reliable food source where the failure of annual crops is common due to adverse weather conditions (Dalbato& Karlsson, 2015).

Enset is a primary staple crop for over 20% of Ethiopia's population (≈18 Million of people), with production and consumption. The average dry matter production per plant is 20 kg placing total production at 2.28 million metric tons. Enset is grown by over 4 million smallholder farmers. Due to its relative drought tolerance, it is regarded as a priority crop in Southern Ethiopia, where it makes a major contribution to the food security of the country. Regions, where Enset is used as staple food, are usually less affected by the recurrent drought periods that occur in Ethiopia (Borrel et al., 2019).

Enset is suitable for sustainable agricultural systems due to its contribution to soil fertility. In addition, Enset can easily be stored without the need for refrigeration and is available throughout the whole year. It can be accessed at any time when there is a food shortage and other crops fail as a result of drought, diseases or other factors (Birmeta et al, 2004). Increases in average temperatures are very likely in the 21st century under both low- and high emissions scenarios. Climate extremes like heavy rainfall, heat waves, and drought, will become increasingly important and will have more significant impacts on Ethiopia crop production (Porter et al., 2014). Therefore, the objective of this paper is to reviews the impacts of climate change on Enset (Ensete ventricosum*)* production and distributions.

LITERATURE REVIEW

Origin and Distribution of Ensete ventricosum

Ensete ventricosum, in Ethiopia, is concentrated in the southern highlands, but also grows in the central and northern highlands. Wild Enset propagates naturally by seed, and is restricted in Ethiopia to elevations of approximately 1,200 to 1,600 meters above sea level. Wild Enset species distributed over much of Asia, and four wild species in sub, Saharan Africa and Madagascar but climate change affect the distribution of Enset (Genet Birmeta, et, al.2004).

Taxonomic and Botanical description of Enset

Enset (Ensete ventricosum) is perennial monocarp crop, belonging to Kingdom: Planate Order Zingiberales and family Musaceae along with bananas. Musaceae is a family of (monocotyledonous) flowering plants. The family is native to the tropics of Africa and Asia consisting of 2 genera, Musa and Ensete, with about 50 species. They are grown mainly for their fruit, the banana, and for their fibers, manila and hemp, used for making rope. They are also grown as ornamental plants. Enset (Ensete ventricosum) is Ethiopia's most important root crop, a traditional staple in the densely populated south and southwestern parts of Ethiopian, climate variability may change its use, species character and its propagation techniques (Genet Birmeta, 2004).

Enset (Ensete ventricosum) is a plant which closely resembles the banana plant; forming a single corm underground and a pseudo stem above the ground. Unlike domesticated bananas

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the seedy leathery fruits of the Enset plant are inedible due to climate changes it may edible. Enset is diploid with n=9. While species of Musa have different ploidy levels (diploid, triploid and tetraploid) with n=10, 11 or 14 and their ploidy level change by climate. Both Ensete and Musa have a large underground corm, a bundle of leaf sheaths (pseudo stem), and large, paddle-shaped leaves. The meristem region is located at the junction point of pseudo stem and underground corm, near the soil surface. Although Enset is thicker and larger than banana, often reaching up to 12 m in height and more than one meter in diameter, both Enset and banana are herbaceous perennial monocarp crops; they produce flowers only once at the end of their life cycle depending on climate variability(Zerihun Yemataw et al., 2012).

When a banana plant dies, it is spontaneously replaced by new suckers sprouting from pre-existing buds in the corm. However, in Enset, sucker production is induced only when the meristem is wounded when the climate variability available. The main sources of food are the corm, pseudo stem, and leaf petioles (Hildebrand, 2001). Most Enset growing areas receive annual rainfall of about 1,100 to 1,500 millimeters, the majority of which falls between March and September in conducive climate. The average temperature of Enset growing areas is between 10 and 21 degrees centigrade, and the relative humidity is 63 to 80 percent. Enset is not tolerant to freezing. Frost damage on upper leaves is commonly observed above 2,800 meters above sea level, and serious stunting is seen above 3,000 meters climate variability can impact its ecology (Borrel et al., 2019).

Impact of Climate Change and Variability

Impact of temperature on Enset production

Temperature is a serious impact on Enset production during climate variability. Climate change is among the major environmental problem of the 21st century. Consecutive reports of the Intergovernmental Panel on Climate Change (IPCC, 2007) and various other Studies (IPCC, 2007; WFP, 2014; Megersa et al, 2014); reveal that climate change is having multiple impacts on human societies and the environment. Scientific evidence indicates that anthropogenic factors are the major contributors to the prevailing global climate change (Forster et al, 2007). The atmospheric concentration of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide has substantially increased over time (Leggett, 2018).

Based on the emission of anthropogenic gases the IPCC has projected that the global average temperature has increased by 0.74 0C in the last century and it is anticipated to 11 increases with 1.1-5.8 0C by the end of this century. Reports by IPCC provided the estimated impacts that would persist on different climate variables under alternative emission scenarios. For instance, assuming no emission control policies, it predicted that average global surface temperatures will increase by 2.8ºC on average during the current century, while the best-guess increases ranging between 1.8 and 4.0ºC (IPCC, 2007).

This increase would alter the natural environmental systems by increasing the frequency of extreme weather events (such as floods and drought), mounting sea levels, changing precipitation patterns and reversing ocean currents. The impacts of these changes on socio-economic activities, and environment health could have serious impacts on long-term implications for the well-being of humans (IPCC, 2014a).

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Temperature has been an increase in seasonal mean temperature in many areas of Ethiopia over the last 50 years and future projection shows that rainfall and temperature anomaly observed, consistent with wider African and global trends (Mcsweeney et al., 2010).

Warming has occurred across much of Ethiopia. Many parts of Ethiopia experience high inter-annual and intra-seasonal rainfall variability which hampers the tracking of trends or changes that could be the result of anthropogenic climate change. Whilst some studies have identified downward trends in parts of the country, comprehensive analysis shows that the situation is not uniform and varies by region or time period (Mcsweeney et al., 2010).

Rising temperatures are hardly surprising, although they do not mean that some parts of the world will not enjoy record cold temperatures and terrible winter storms. Heating disturbs the entire global weather system and can shift cold upper air currents as well as hot dry ones. Single snowballs and snowstorms do not make climate change refutations. Increasingly, however, hot, dry places will get hotter and drier, and places that were once temperate and had regular rainfall will become much hotter and much drier (Kumar, 2016).

The string of record high temperature years and the record number of global droughts of the past decade will become the norm, not the surprise that they have seemed. Global warming is projected to have a number of effects on the oceans. Ongoing effects include rising sea levels due to thermal expansion and melting of glaciers and ice sheets, and warming of the ocean surface, leading to increased temperature stratification (Deser, 2017).

Impact of precipitation on Enset production

The main danger of heavy rains to Enset is that roots and the corm do not tolerate water-logging for long periods. For that reason, Enset is usually grown in soils that do not have high water tables and are well drained. Enset grows well in most soil types, if they are sufficiently fertile and well drained of water. Cattle manure is used as the main organic fertilizer. Manure increases water holding so that soil water endures longer into the dry season, and reduces the negative effects of the high clay content of vertisols. The ideal soils climate in Enset growing areas are moderately acidic to alkaline (pH 5.6 to 7.3) and contain two to three percent organic matter (Borrel et al., 2019).

There are a lot of number strong evidence for consistent climate changes in seasonal and annual rainfall totals or the frequency and intensity of extreme events in Ethiopia. Computer-based global climate models form the basis for descriptions of future climate conditions and risk assessment. Overall climate models simulate continued warming but very mixed patterns of rainfall change for Ethiopia. Warming occurs in all four seasons with annual warming by the 2020s 1.2°C higher than it is at present, with a range of 0.7-2.3°C (2050s 2.2°C, range 1.4-2.9°C). This warming will be associated with more frequent heat waves and may affect evaporation of precious soil moisture during crop growing seasons. Some climate models project more rain, others less, but with a tendency for slightly wetter conditions. Overall, there are relatively small changes (~1%) in average annual rainfall by the 2020s and 2050s. The seasonal changes are slightly larger but still modest when averaged across all climate models. In cases where uncertainty about future climate risks is very high, such as in Ethiopia (and many other parts of Africa), there is a strong case for using recent climate observations (in situ

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and remotely-sensed) as a guide to conditions during the next decade. This requires regular updating and comparison with climate model results (IPCC, 2007).

Heavy rainfall can lead to numerous hazards, for example: flooding, including risk to human life, damage to buildings and infrastructure, and loss of crops and livestock. Landslides, which can threaten human life, disrupt transport and communications, and cause damage to buildings and infrastructure. However, a combination of not enough watering and no rainfall could also lead to dying crops. Under watering "starves" the plant of water, which can lead to crop death or low yield. Conversely, overwatering can lead to browned tips of crop leaves and also possible root rot and other issue Climate change can disrupt food availability, reduce access to food, and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity. Rain is liquid water in the form of droplets that have condensed from atmospheric water vapor and then become heavy enough to fall under gravity. Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. Precipitation occurs when a portion of the atmosphere becomes saturated with water vapor, so that the water condenses and "precipitates". Thus, fog and mist are not precipitation but suspensions, because the water vapor does not condense sufficiently to precipitate. A greenhouse gas (sometimes abbreviated GHG) is a gas that absorbs and emits radiant energy within the thermal infrared range. Greenhouse gases cause the greenhouse effect. The primary greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide and ozone (Conway & Schipper, 2011)

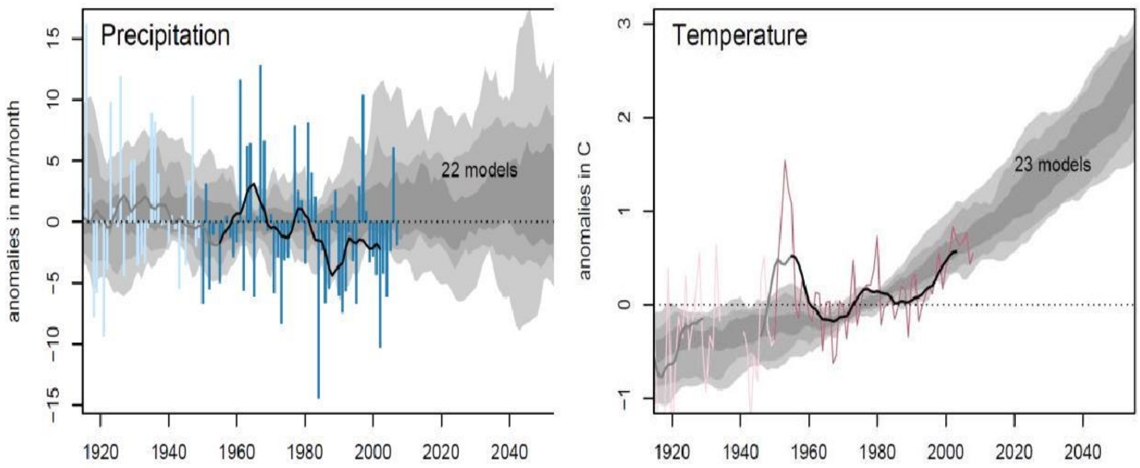

Figure 1: Observed precipitation and temperature changes in Ethiopia (annual averages) along with simulated changes by 22/23 global climate models (IPCC, 2007).of Enset.

Climate Change and Enset Yield Relationships

Along with increases in temperature, global warming is associated with changes in large-scale hydrological cycle elements, such as an increase in atmospheric water vapor, shifting precipitation patterns, changes in precipitation intensity and extreme events, reduced snow

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cover and extensive melting of ice, and variations in soil moisture content and runoff (Bates et al. 2008; Hartmann et al. 2013).

Climate change is projected to overall decrease the yields of Enset crop in Africa through shortening growing season length, amplifying water stress and increasing incidence of diseases, pests and weeds outbreaks (Niang et al. 2014). Among the various environmental changes brought about by the climate change that limit crop yields, heat and water stresses are considered the most important (Prasad et al. 2008). Heat stress during development phases leads to fewer and smaller organs, reduced light interception due to shortened crop life, and altered carbon-assimilation processes including transpiration, photosynthesis, and respiration (Stone 2001).

Increase in temperature also increases saturation vapor pressure of air, thereby increasing evaporative demand. Plants close their stomata as a response to increased evaporative demand, thereby reducing photosynthesis rate and increasing vulnerability to heat injury (Lobell and Gourdji, 2012).

Even short duration heat shock can reduce crop yield substantially, especially if it coincides with the reproductive stage (Teixeira et al. 2013). Meanwhile, water stress leads to the shortening of the crop reproduction stage, reduction in leaf area and closure of stomata to minimize water loss, reducing crop yields (Barnabás et al. 2008). The occurrence of water and heat stresses adversely impact plant growth and productivity, which is more pronounced than the individual impacts (Prasad et al. 2008). However, in areas with excess water and heat (due to climate change) it is projected that pathogen, weed, and insect infestation will further damage the agricultural systems (Ziska et al. 2011).

Climate Projections

Due to the inherent uncertainty of the climate system and the inevitable existence of model errors, multi-model ensemble is the recommended approach for climate change projections. Several climate models have been developed and currently used to simulate the behavior of the climate system. The ultimate objective is to understand the key physical, chemical and biological processes which govern the climate systems. Through understanding of the climate system, it is possible to obtain a clearer picture of past climates and associated processes by comparison with empirical observation, and predict future climate change based on some key assumptions. Models can be used to simulate climate on a variety of spatial and temporal scales (Vuuren et al, 2011, Moss et al, 2014).

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An alternative, Regional Climate Models (RCMs) were introduced to provide more detailed climate simulations for various regions on the globe. RCMs statistically downscale GCM output to scales more suitable to end user needs (Kilsby et al, 2007) and are useful for understanding climate variability and change particularly in regions with complex topographical detail such as Ethiopia. These models are nested within global models and are fed across lateral boundaries by information produced by the GCMs or observational fields. It should be, however, emphasized that RCMs are not formulated to replace GCMs but rather to supplement GCMs by adding fine scale detail to their coarser resolution simulations (Kilsby et al., 2007).

Climate Scenarios and Variability

Scenarios are plausible combinations of conditions that can represent possible future situations. Scenarios are often used to assess the consequences of possible future conditions, how organizations or individuals might respond, or how they could be better prepared for them. For example, businesses might use scenarios of future business conditions to decide whether some business strategies or investments make sense now. Climate change scenarios are scenarios of plausible changes in climate. We use them to understand what the consequences of climate change can be. We can also use them to identify and evaluate adaptation strategies (Hulme et al., 2018).

We create climate change scenarios because predictions of climate change at the regional scale have a high degree of uncertainty. By regional scale, we typically mean the sub-continental scale to country level to provincial level. Although it is likely that temperatures will eventually rise in most regions of the world, changes at the regional scale in many other key variables, such as precipitation, are uncertain for most regions. Even where the direction of change is certain or likely, there is uncertainty about the magnitude and path of change. We create scenarios as tools to help us understand how regional climates may change so as to understand how sensitive systems may be affected by climate change (Houghton al, 2001).
Weather forecasts make use of enormous quantities of information on observed state of the atmosphere and calculate, using the laws of physics, how this state will evolve during the next few days, producing a prediction of the future (IPCC, 2007).

Climate scenario is a plausible indication of what the future could be like over decades or centuries given a specific set of assumptions. These assumptions include future trends in energy demand, emissions of GHG, land use change as well as assumptions about the behavior of the climate system over long time scales. It is largely the uncertainty surrounding these assumptions which determines the range of possible scenarios. The criteria (consistency with global projections, physical plausibility, and applicability in impact assessment, representative and accessibility) that should be met by climate scenarios if they are to be useful for impact research and policy makers (Hulme et al., 2018).

Climate scenarios are of three main types which have been employed in impact assessment: Synthetic scenario, analog scenarios and climate model-based scenarios (IPCC, 2007). In this impact study climate model-based scenarios were applied. Climate models at different resolution and complexity serve as the major source of information for constructing scenarios. The most common method of developing climate scenarios for quantitative impact assessment is to use result from GCMs and RCMs. These numerical models representing physical

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processes in the atmosphere, ocean, cry sphere and land surface are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentration (IPCC, 2007). GCMs depict the climate using a three dimensional grid over the globe, typically having a horizontal resolution of between 250 and 600 km, 10 to 20 vertical layer in the atmosphere and sometimes as many as 30 layers in the oceans, whereas RCMs have a horizontal resolution of about 50 km or less(IPCC, 2007).

Climate Model and Future of Climate Change

Climate models use quantitative methods to simulate the interactions of the important drivers of climate, including atmosphere, oceans, land surface and ice. They are used for a variety of purposes from study of the dynamics of the climate system to projections of future climate Climate models use quantitative methods to simulate the interactions of the important drivers of climate, including atmosphere, oceans, land surface and ice. They are used for a variety of purposes from study of the dynamics of the climate system to projections of future climate. Climate models may also be qualitative (i.e. not numerical) models and also narratives, largely descriptive, of possible futures.(IPCC, 2014).

Spatial crop suitability modeling is conducted to estimate where a specific crop can be produced given different environmental factors, including current and future climate scenarios. Crop suitability model outcomes can also provide crop breeders with decision support for targeting genotypes to environments or for identifying future requirements in crop adaptation (Beebe et al., 2011). Empirical and mechanistic crop growth models and applied a threshold to the 22 predicted yields to assess the suitability of banana and plantain (*Musa* spp) under current and future climates. Enset suitability models can be potentially useful tools for strategic spatial planning of agricultural activities, including risk assessments, as these models are capable of reproducing regional and global trends in Enset production (Ramirez-villegas., 2013).

Climate models attempt to simulate the behavior of the climate systems. The ultimate objective is to understand the key physical, chemical and biological processes which govern climate. Through understanding the climate system, it is possible to: obtain a clear picture of past climates by comparison with empirical observation, and predict future climate change. There have been several studies used a different modeling approach to simulate the climate suitability for Enset production (Ramirez-villegas., 2013).

Enset growth simulation models are research tools usually applied in assessing the relationship between Enset productivity and environmental factors. They have been shown to be efficient in determining the response of Enset plants to changes in weather and climate. In most of the cases, these Enset models have been developed in particular localities and they are not always applicable in other regions without modification. Therefore, when introducing such Enset models into new regions, their applicability needs to be evaluated (IPCC, 2014).

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CONCLUSSION

The multiple drivers of food insecurity in Ethiopia including drought risk, environmental degradation, demographic pressure, rural-urban migration, and conflict. In the absence of adaptation measures, climate variability and change act as risk multipliers, exacerbating the conditions which affect food security trends there must coping mechanism needed to adapt the coming disaster of climate change and variability. Climate change scenarios are scenarios of plausible changes in climate. We use them to understand what the consequences of climate change can be. We can also use them to identify and evaluate adaptation strategies. Increases in average temperatures are very likely in the 21st century under both low- and high emissions scenarios. Climate extremes like heavy rainfall, heat waves, and drought, will become increasingly important and will have more significant impacts on Ethiopia crop productionThe agriculture sector has also the capacity to produce adaptation measure against climate change. Enset is not affected by occasional heavy rainfall. This resilience is attributed to the plant's stiff leaves, which resist large raindrops. In fact, one of the main attributes of enset is that it protects the soil from erosive rainfall. Enset is a crop that tolerates prolonged drought periods and many diseases

To conclude that climate suitability for Enset growing area, EcoCrop simplest model was selected to assess the impacts of progressive climate change. The model was found to perform well when predicting suitable area under present and future conditions. The model has projected the impacts of climate change on enset growing condition.

REFERENCE

Blomme, G., Dita, M., Jacobsen, K.S., *et al.* 2017. Bacterial diseases of bananas and enset: current state of knowledge and integrated approaches toward sustainable management. Frontiers in Plant Science 8, 1290.

Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Xiaosu, D., Maskell, K., Johnson, C.A., 2001. Climate Change 2001: The Scientific Basis. Cambridge University Press, New York.

IPCC, 2014. "AR5 Synthesis Report - Climate Change 2014. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change" (PDF): 58. Box 2.3.

Paul, D., Sebsebem W,, Kathym W., Feleke, D., Aaron, P., Molla Ermias, L., Janssens, S., Kallow, S., Berhanu, A., 2019. Enset in Ethiopia: a poorly characterized but resilient starch staple". Annals of Botany. 123 (5): 747–766. Doi: 10.1093/aob/mcy214. PMID 30715125.

O'Brien, K.L., Leichenko, R.M., 2000. Double exposure: Assessing the impacts of climate change within the context of economic globalization. Global Environmental Change 2000, *10*, 221–232.

@ECRTD-UK https://www.eajournals.org/
https://doi.org/10.37745/ejafr.2013

IPCC. Climate Change 2014: Synthesis Report; Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Pachauri, R.K., Meyer, L.A., Eds.; IPCC: Geneva, Switzerland, 2014; p. 151.

Bermenta, G., Nybom, H., Bekele, E., 2004. Distinction between wild and cultivated Enset (Ensete ventricosum) gene pools in Ethiopia using RAPD markers. */ Hereditas 140: 139-148. Lund, Sweden. ISSN 0018-0661.

Zerihun Yemataw, Husen Mohamed, Mohammed Diro, Addis Temesgen, and G. Blome (2014). Ethnic-based diversity and distribution of Enset (ensete ventricosum) clones in southern Ethiopia. Journal of ecology and the natural environment

Endale, T., Mulugeta, D., Gizachew, W.M., Gebre, Y., Masayoshi, S., Shiferaw, T., 1997. The Tree against Hunger. Enset-Based 56 Agricultural Systems in Ethiopia. Brenner Congressional Action on R&D in the FY 1997 Budget.

Hildebrand, E., 2001. Morphological characterization of domestic vs. forest-growing Ensete ventricosum (Welw.) Cheesman, Musaceae, in Sheko district, Bench-Maji Zone, southwest Ethiopia. Biodiversity research in the horn of Africa region. Biologiske Skrifter 54, 287-309.

Tsegaye, A., Struik, P.C., 2001. ENSET (Ensete ventricosum (Welw) Cheesman) Kocho yield under different crop establishment methods as compared to yields of other carbohydrate-rich food crops. Netherlands Journal of Agricultural Science 49, 81-89.

Ramirez-villegas., et al. (2013). Agricultural and Forest Meteorology Empirical approaches for assessing impacts of climate change on agriculture: The EcoCrop81model and a case study with grain sorghum.

Ramirez, J., Jarvis, A., Bergh, I.V.D., Staver, C., Turner, D., 2011. Chapter20 Changing Climates: Effects on Growing Conditions for Banana and Plant an in (*Musa* spp.) and Possible Responses.

Ranjitkar, S., Sujakhu, N.M., Merz, J., Kindt, R., Xu, J., Matin, A., Zomer, R.J., 2016. Suitability Analysis and Projected Climate Change Impact on Banana and Coffee Production Zones in Nepal. *Plos One*, 1–18.https://doi.org/10.1371/journal.pone.0163916.

Sindhu, J.S., 2011. Potential impacts of climate change on agriculture. Indian Journal of Science and Technology, 4(3). 348-353

Vuuren, D. P. Van, Edmonds, J., Kainuma, M., Riahi, K., Nakicenovic, N., Smith, S.J., & Rose, S. K. (2011). The representative concentration pathways: an overview. Climatic Change, 5–31. https://doi.org/10.1007/s10584-011-0148-z.

Walthall, C.L., J. Hatfield, P. Backlund, L. Lengnick, E. Marshall, M. Walsh, S.Adkins, M. Aillery, E. A. A., C. Ammann, C.J. Anderson, I. Bartomeus, L.H.Baumgard, F. Booker, B. Bradley, D.M. Blumenthal, J. Bunce, K. Burkey, S.M.Dabney, J.A. Delgado, J. Dukes, A. Funk, K. Garrett, M. Glenn, D.A. Grantz, D.Goodrich, S. Hu, R. C. I., R.A.C. Jones, S-H. Kim, A.D.B. Leaky, K. Lewers,T.L. Mader, A. McClung, J. Morgan, D.J. Muth, M. Nearing, D.M. Oosterhuis,D. Ort, C. Parmesan, W.T. Pettigrew, W. Polley, R. Rader, C. Rice, M.Rivington, E. Rosskopf, W. A. S., & L.E. Sollenberger, R. Srygley, C. Stöckle,E.S. Takle, D. Timlin, J.W. White, R. Winfree, L. Wright-Morton, L. H. Z. (2012). Climate Change and Agriculture in the United States: Effects and Adaptation. USDA Technical Bulletin 1935. Washington, DC. 186 Pages.

Wayne, G.P., 2013. Representative Concentration Pathways. Skeptical Science.

WFP, 2014. Climate risk and food security in Ethiopia: Analysis of climate impaction food security and livelihoods.

Megersa, B., Markemann, A., Angassa, A., Ogutu, J.O., Piepho, H.P., Valle Zaráte, A., 2014. Impacts of climate change and variability on cattle production in southern Ethiopia: Perceptions and empirical evidence. Agricultural Systems, 130, 23–34. https://doi.org/10.1016/j.agsy.2014.06.002

Mcsweeney et al., C., New, M., & Lizcano, G. (2010). UNDP climate change profileforEthiopia:Http://Www.Geog.Ox.Ac.Uk/Research/Climate/Projects/UndpCp/Index.HtmlCountry=Ethiopia&d1=Reports, 1–27

Leggett, J. A., 2018. Evolving Assessments of Human and Natural Contributions to Climate Change. Congressional Research Service.

Mali, V. S. P.-P. And S. P. (2015). Open Access Short Communication EcoCropModel Approach for Agro-Climatic Sugarcane Crop Suitability in BhogawatiRiver Basin of Kolhapur District, Maharashtra, India Abstract : Universal Journal of Environmental Research and Technology, 5(5), 259–264.

Kurukulasuriya, P., & Rosenthal, S. (2003). Climate Change and Agriculture. The World Bank Environment Department, (91).

IPCC. (2014). Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 10.

IPCC. (2014a). *CLIMATE CHANGE 2014* Mitigation of Climate Change Summary for Policymakers and Technical Summary Mitigation of Climate Change.

IPCC. (2014b). United Nations Framework Convention on Climate Change. United Nations Framework Convention on Climate Change, (February 2011), 1–7.https://doi.org/10.1111/j.1467-9388.1992.tb00046.x

Hatfield, J.L., Antle, J., Garrett, K.A., Izaurralde, R.C., Mader, T., Marshall, E., Ziska, L., 2018. Indicators of climate change in agricultural systems. Climatic Change. https://doi.org/10.1007/s10584-018-2222-2 Indicators.

Forster et al., P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J.Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. P., & G. Raga, M. S.and R. V. D. (2007). Changes in Atmospheric Constituents and in Radioactive Forcing (IPCC 2007). Cambridge University Press, Press, Cambridge, United Kingdom and New York, NY, USA.30 (22), 129–234.https://doi.org/10.1103/PhysRevB.77.220407

Dalbato, A. L., & Karlsson, L. (2015). Enset agriculture as adaptation strategy to climate change, 2015.

Conway, D., Schipper, L., 2011. Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. Global Environmental Change, 21(1), 227–237.

Beebe, S., Ramirez, J., Jarvis, A., Rao, I. M., Mosquera, G., Bueno, J. M., & Blair, M.W. (2011). Chapter 16 Genetic Improvement of Common Beans and the Challenges of Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Pp. 1199-1265.

IPCC. Climate Change 2014: Synthesis Report; Contribution of Working Groups I, II and III to the Fifty Assessment Report of the Intergovernmental Panel on Climate Change; Pachauri, R.K., Meyer, L.A., Eds.; IPCC: Geneva, Switzerland, 2014; p. 151.

Kotir, J.H., 2011. Climate change and variability in Sub-Saharan Africa: A review of current and future trends and Impacts on agriculture and food security. Environ. Dev. Sustain. 2011, 13, 587–605.

Adeniyi, P.A., 2016. Climate change induced hunger and poverty in Africa. J. Glob. Biosci., 5, 3711–3724.

AGRA (Alliance for a Green Revolution in Africa Change). Smallholder Agriculture in Sub-Saharan Africa; AGRA: Nairobi, Kenya, 2014.

Adger, W.N., Huq, S., Brown, K., Conway, D., Hulme, M., 2003. Adaptation to climate change in the developing world. Progress in Development Studies 2003, 3, 179–195.

Sagoe, 2006; estimation of climate change of agricultural productivity, in Ghana

Deser, C., Ruixia, G., Flavio, L., 2017. "The relative contributions of tropical Pacific sea surface temperatures and atmospheric internal variability to the recent global warming hiatus." Geophysical Research Letters 44.15 (2017), 7945-7954.

Hartmann, D.L., Klein Tank, A. M. G., Rusticucci, M., Alexander, L. V., Bronnimann, S., Charabi, Y., et al. 2013. Observations: atmosphere and surface. Pp. 159–254 *in* T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, et al., eds. Climate change 2013: the physical science basis. Contribution of Working Group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, United Kingdom and New York, NY, USA.,

Niang, I., O. C. Ruppel, M. A. Abdrabo, A. Essel, C. Lennard, J. Padgham, et al. 2014. Africa. Pp. 1199–1265 *in* V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, L. L. White, eds. Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, United Kingdom and New York, NY.

Prasad, P. V. V., S. A. Staggenborg, and Z. Ristic. 2008. Impacts of drought and/or heat stress on physiological, developmental, growth and yield processes of crop plants in L. H. Ahuja, L. Ma and S. Saseendran, eds. Responses of crops to limited water: understanding and modeling water stress effects on plant growth processes. Advances in Agricultural Modeling Series 1, 301–355. ASA-CSSA, Madison, WI, USA.

Stone, P., 2001. The effects of heat stress on cereal yield and quality. *in* A. S. Basra, ed. Crop responses and adaptations to temperature stress. Food Products Press, Binghamton, NY, Pp. 243–291

Bita, C.E., Gerats, T., 2013. Plant tolerance to high temperature in a changing environment: scientific fundamentals and production of heat stress-tolerant crops. Frontiers in Plant Science 4, 273.

Lobell, D. B., and S. M. Gourdji. 2012. The influence of climate change on global crop productivity. Plant Physiology 160, 1686–1697.

Alqudah, A.M., Samarah, N.H., Mullen, R.E., 2011. Drought stress effect on crop pollination, seed set, yield and quality. Pp. 193–213 *in* E. Lichtfouse, ed. Alternative farming systems, biotechnology, drought stress and ecological fertilization. Springer, Dordrecht, the Netherlands.

Conway, G. 2009. The science of climate change in Africa: impacts and adaptation. Discussion Paper, 1. Grantham Institute for Climate Change, Imperial College London, London, United Kingdom

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https://doi.org/10.37745/ejafr.2013

Welu, G. (2015). "Effects of Plant Density on the Yield Components of Haricot Bean (*Phaseolus vulgaris* L.)." Journal of Natural Sciences Research **5**(5), 37-41.

Bates, B.C., Kundzewicz, Z.W., Wu, S., Palutikof, J.P., 2008. Climate change and water. Technical Paper of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, Switzerland.

@ECRTD-UK https://www.eajournals.org/
https://doi.org/10.37745/ejafr.2013