



Review Article

Impact of Climate Change on the Diversity and Distribution of Enset (*Ensete ventricosum* (Welw) Cheesman) in Ethiopia: A Review

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Abstract: The aim of this review paper is to review the impact of climate change on diversity and distribution of enset in Ethiopia and to suggest the gaps for future research. Climate change impacts will disproportionately affect sub-Saharan African countries such as Ethiopia because their economies are highly dependent on climate-sensitive activities such as rain-fed agriculture. In Ethiopia, climate change and associated extreme events are causing significant damage to life, property, natural resources and the economy by affecting climate sensitive sectors such as agriculture. Of the influence of climate change in Ethiopia crop species diversity and distribution is the current issue to deal with. Big genetic erosion and limitation of production of crops toward the high lands parts of the country in general and enset in particular is under way. Species distributions are determined by a range of different factors, among which climate is one of the most important ones. Climate change based distribution of enset is currently observed in Ethiopia. In some part of the country the enset production is shifting to the high land areas due to the changing climatic conditions. Some of the clones are struggling for tolerance of the changing environment, while others shift toward higher altitude; the others are unable to withstand the changing climatic condition and are enforced to die. Recent climate change has become one of the main drivers of shifts in the geographical distributions and diversity of enset species in Ethiopia. Therefore, urgent and appropriate actions are needed within various scenarios of climate change impacts on biodiversity and species distribution of enset.

Keywords: Species, Diversity, Distribution, Enset, Temperature, Highland, Biodiversity Loss

1. Introduction

Enset (*Ensete ventricosum* (Welw) Cheesman) (2n=18) is a perennial herbaceous, monocarpic and monocotyledonous crop that belongs to the family Musaceae and fruits only once in its life cycle (after 6–10 years) depending on climate and landrace. It is known as Ethiopian banana, Abyssinian banana or false banana due to its morphological resemblance with banana [15].

Musa families are widely distributed from eastern edge of great African plateau, extending northwards from South

Africa through Mozambique, Zimbabwe, Malawi, Kenya, Uganda and Tanzania to west of Congo, being found in rainforests on mountains, and along forested ravines and streams. However, the genus ensete under Musa family domesticated in Ethiopia 8000 years ago with the area encompassing more than 80% of the enset production of the country [1]. It is widely distributed and cultivated in south and southwestern part of Ethiopia.

Enset can significantly help to ensure food security in a

country like Ethiopia [62]. It is a traditional staple crop for about 20 million of the population of the people living in the densely populated regions of South and Southwestern Ethiopia. Enset is also utilized for livestock feed, fuel wood, construction materials, containers, and to shade other crops [52]. Enset is a multipurpose crop which is utilized for human food, animal feed, medicinal or ornamental uses. Farmers indicate that enset is their food, their cloth, their house, their bed, their cattle feed and their plate [62]. The corm and the pseudo stem are the most important sources of food [35]. The major food types obtained from enset are kocho, bulla and amicho. Enset fiber is used for making bags, ropes, twines, cordage, and mats.

Enset is grown at altitudes from 1500-3100m.a.s.l, but scattered plants can also be found at lower altitudes. For optimum growth, the plant requires an average rainfall of 1100-1500 mm per year and a mean temperature of 16-20°C. Enset grows well in most soil types, provided they are sufficiently fertile and well-drained. The ideal soils are moderately acidic to alkaline (pH 5.6 to 7.3) with 2-3% organic matter [49].

The impact of climate change on diversity and distribution crop is one of the most pressing questions in ecology and biodiversity conservation. The presence and distribution of wild species is closely related to their agro climatic requirements and how those requirements are satisfied in various environments [51].

Crop diversity and distribution variation within and among present crop plant may be due to genetic or agro-ecology in which they occur [49], as a result of human factors, cultural, population pressure, ecological variation or interaction between genetic and environmental factors as well as household resources [2, 18].

Climate change poses huge challenges to the global economy and to social development. Its impacts will disproportionately affect sub-Saharan African countries such as Ethiopia because their economies are highly dependent on climate-sensitive activities such as rain-fed agriculture. In Ethiopia, climate change and associated extreme events are causing significant damage to life, property, natural resources and the economy by affecting climate sensitive sectors such as agriculture [29, 32, 62].

In Ethiopia the enset diversity and distribution is done; but is more or less of morphological and ethnic based. Climate change based diversity and distribution is not well addressed. Of the influence of climate change in Ethiopia crop species diversity and distribution is the current issue to deal with. Big genetic erosion and limitation of production of crops toward the high lands parts of the country in general and enset in particular is under way. Keeping this and the above issues of climate change impact in mind, this review is proposed to review the influences of climate change on diversity and distribution of enset in Ethiopia and to suggest the gaps on climate change effect on enset diversity and distribution in Ethiopia for future research.

2. Review of the Influence of Climate Change on the Diversity and Distribution of Enset in Ethiopia

2.1. Enset Diversity and Distribution in Ethiopia

Ethiopian highlands are center of origin for enset. Reports of landrace diversity in enset are numerous. Names of 99 enset clones were reported in the North Omo area [4]. There is also report showing enset clones from three zones; 52 clones from Sidama, 55 clones from Walayita and 59 clones from Hadiya [3].

Farmers maintain and enrich the diversity of enset, and select or classify clones for various uses [44]. About 218 enset diversities were also identified in eight zone of SNNP [63]. In addition 111 enset clones were characterized based on quantitative and qualitative traits as well as use value it contributes [40].

Moreover, about 86 enset clones (clones) in the south and southwestern part of Ethiopia were recorded respectively [2] [19]. In the survey conducted in Wolaita zone about 67 enset clones were recorded; of which 31 clones from lowland and 52 clones from high and mid-land area [54]. Seventy eight vernacular names of cultivated enset clones were listed in arid area of southern Ethiopia [51]. 312 enset clones were identified from eight zones in southern Ethiopia [13]. Sixth one [8], and 79 enset clones [55] were recorded in Sidama Zone, Southern Ethiopia. Furthermore, 146 enset clones described in five different regions in southern and southwestern Ethiopia [5]. The result revealed that in each kebele, enset clones are very diverse ranging from 2 to more than 50 clones [1]. Survey conducted at Keffa zone in two districts namely, Chenna and Decha and 42 different enset varieties were identified [61].

2.2. Influence of Climate Change on Enset Diversity in Ethiopia

Globally, biodiversity is being lost and increasingly threatened through a range of anthropogenic actions. The most important notable drivers behind the current loss of biodiversity are habitat modification, overexploitation, climate change, invasive alien species, and chains of extinction, known collectively as the evil five biodiversity threats [14, 22-28].

Ethiopian farmers are facing severe consequences because of climate changes, and the majority population of Ethiopia is especially vulnerable to climate change impacts. Diversity disturbance of enset is of the influences of climate change [11, 16].

Global climate change is often considered as one of the major factors causing biodiversity loss. Recently, study has been reported that landraces of enset declining from time to time. Diversity studies acquire current information on the occurrence, extent, abundance and spatial dynamics of the available diversity which is instrumental for planning and implementation of effective in situ and ex situ conservation

strategies [6].

Enset diversity study in Ethiopia is majorly focused on morphological feature, ethnic based farmer's indigenous classification. There is a report showing highest species diversity at higher altitude above 2500m [40]. Enset clones from the three agro-ecological content of the study areas were identified with 52 from high and midland area where as 31 enset species were from lowland agro-ecology. Within these agro-ecologies 22 enset clones were the common share across the 3 agro-ecologies [54].

Enset landraces are not evenly distributed across the region mainly due to altitude variations [55]. Numerous enset clones were identified in each region and the variations in the number of clones were attributed to a combination of socio-cultural and agro ecological factors [3]. Furthermore, reported that the observed genetic diversity in cultivated enset in a particular area appears to be related to the extent of enset cultivation and the culture and distribution pattern of the different ethnic groups [54].

The highest number of clones shared was registered in pairs of kebeles between, Gurmina Hangeri and Meleka, and Ediya and Gurmina Hangeri where each kebeles cultivate 18 clones [9]. This might be due to the existed variability in climatic factors such as temperature, rainfall (abundance and distribution), humidity within a close range of altitudes is similar. The variation in number of clones per farm become higher among farms found between high altitudinal range differences.

There is also a research reported on the presence of a large number of similar clones in pair of Zones in southern Ethiopia, namely: Hadiya/Kembata, Gurage/Silte, and Dawero/Wolaita [65]. This could be, the agro-ecology of high land area is very suitable for presence of enset variety and productivity [13]. Another report in Sidama zone Aleta Chiko district of five kebeles reported that the highest share of clones recorded between kebeles found under close altitudinal variation, while the lowest share scored between kebeles found in higher altitudinal variation [13].

Woinadega (3.86) had more diverse enset landraces than dega (3.85) and dry w/dega (2.79) [20]. This is probably for the reason that w/dega had both dega and dry w/dega agro-ecological characteristics. But highest number of varieties per household was identified in dega than the other zones. This shows that the enset growing area has high adaptation capacity than the limited growing area [20].

Predictions of climate induced extinction rates are uncertain and expert opinions differ on the extent of loss due to the great deal of uncertainty regarding the number of species that exist on earth. For instance, [42] found that 19 species have been extinct due to climate change. The International Union for Conservation of Nature Red List of Threatened Species predicted that 4161 species are being threatened by climate change, 33% are at the risk from climate change-induced habitat shifts and alteration, 29% are due to temperature extremes, and 28% are due to drought [57, 7].

The differences in landrace diversity between each Kebele were directly related to altitude. This means as altitude

increases, the number of enset landrace also increases. There existed significant ($p < 0.05$) and strong positive linear relationship ($r = 0.85$) between the diversity of enset landraces and altitude [12]. Similarly, as the study conducted on diversity of enset landraces in Sidama zone the number of landraces was lower at lower altitudes while reached maximum at highest altitude (2400m.a.s.l) [55].

2.3. Influence of Climate Change on Enset Distribution in Ethiopia

Species distributions are determined by a range of different factors, among which climate is one of the most important ones. It is numerously documented that species have shifted their ranges in response to the climatic fluctuations during the Pleistocene. During the last century, global average temperature has risen by approximately 0.7°C, due to anthropogenic greenhouse gas emissions. Contemporary climate change has been shown to cause range shifts of species as well as changes in phenology, physiology or morphology [39]. When climatic conditions change, a species can respond by moving, adapting or going extinct [59-61]. It is acknowledged that the distributions of species and communities are strongly determined by the climatic conditions under which they have developed and climate also controls global patterns of the structure and productivity of vegetation affecting not only the composition of plant and animal species but also aspects such as phenology, migratory processes, and the temporal dynamics of distributional ranges [50].

The presence and distribution of wild species is closely related to their agro climatic requirements and how those requirements are satisfied in various environments. The presence of climate change may threaten the satisfaction of these requirements and thus for the presence and distribution of wild species [48]. Plant communities at mountain tops have more imposing restrictions by the increase in temperature, as well as a reduction in the available area because the peaks of mountains occupy smaller spaces [39], which restrict the migration of species to areas with favorable conditions for their development.

Geographic distribution of biological entities is limited in time and space because of the variation of their tolerance to ecological factors, so they can be successful only in a more or less restricted interval in one environmental gradient. Hence, vegetation in a given place can be related to the influence of several climatic variables. Thus, climate becomes one of the main factors at a regional scale that allows predictions of plant communities' distribution patterns [10].

The broad conclusion of literature results shows that many species have shifted their geographic ranges in response to rapid changes in temperature and precipitation regimes, generally poleward, toward higher elevations. In terrestrial environments, plants and animals moved toward higher elevations at the rate of 0.011 km per decade and to higher latitudes at the rate of 16.9 km per decade [31]. Climate change has resulted in dramatic shifts in the geographical distributions of east African species and ecosystems [33, 34,

36, 38].

Climate change has already affected a wide array of taxa [58] causing distributional shifts or even extinctions of plant and animal species and, further, leaving “fingerprints” across ecosystems and biodiversity. Climate change has been reported to force plants to move toward higher elevations and latitudes, and to lead to habitat loss and fragmentation and range contractions of species [30]. These impacts could alter species distributions and biodiversity patterns, and plants’ geographical ranges become small and isolated, leading to high risks of extinction.

Species affected by climate change may respond in three ways: change, move or die. Local species extinctions or a rapidly affected ecosystem as a whole respectively might move toward its particular tipping point, thereby probably depriving its services to human society and ending up in a global crisis [47, 53].

Local communities are disaggregating and encompassing more warm-adapted species. Phenological changes in populations, including shifting breeding cycles or deferred peaks of growth periods, are decoupling species interactions. Phenological shifts in flowering plants are potentially initiating the incompatibilities between plant and pollinator population. This may lead to the extinctions of both the plants and the pollinator with expected consequences on the structure of such mutualistic networks [58].

The multiple components of climate change i.e., temperature, rainfall, extreme events, carbon dioxide concentrations and ocean dynamics are anticipated to affect all levels of biodiversity: gene-, species- and habitat-diversity. At the very basic level of biodiversity, climate change is able to lessen genetic diversity of populations due to directional selection, genetic drift, population differentiation and rapid migration. As a consequence the probability of population adaptation to new environmental conditions is reduced and thus the risk of extinction increases. Furthermore, altered species compositions and interactions are considered to directly affect ecosystem functioning and resilience [58].

Global climate change has already had large effects on populations and distributions of species across the globe [21] and the shifting distributions and abundances of species will have important consequences for the future of biodiversity [45].

Recent climate change has become one of the main drivers of shifts in the geographical distributions of plant species. There are several ways in which species can respond to climate change: adapt, move in different directions in order to track suitable climates, (i.e. towards higher latitudes and elevations, or to the east and west) and go extinct locally, regionally, or, in a worst case scenario, globally [21].

Climate is one of the determinant factors for species distribution. Species ranges shift due to climate change are determined by: abiotic ally limited relicts in which their distribution and physiological activities is constrained by lack of sufficient environmental variables related to climate change; biotical limited relicts in which biotic perturbations such as competition is minimal for climatic reasons; and biotical

sustained relicts which require a host or mutualistic limited to climate change for their existence [28].

Out of the 99 species in research of species range shift, 80% of them showed shifts in range distribution [46]. The average pole ward (latitude) and upward (elevation) shift was 6.1 ± 2.4 km and 6.1 m decade⁻¹ respectively. However, there is a report showing 17.6 km and 12.2 m decade⁻¹ latitudinal and elevation range shift respectively [21].

Man-induced climate change, which could be considered as the sixth species mass extinction, is one of the major threats to biological diversity. Out of the estimated 5 million terrestrial species, 18-34% species are at risk of extinction caused by climate change [56]. Thus, if species and communities are unable to withstand the ever changing climate through the previously mentioned ways and; we are unable to mitigate climate change; species extinction would be the worst in our history. The worst thing is the speed of climate change is faster than the response of species and communities to withstand the impact of climate change [17].

Climate change based distribution of onset is currently observed in Ethiopia. In some part of the country the onset production is shifting to the high land areas due to the changing climatic conditions. Some of the clones are struggling for tolerance of the changing environment, while others shift toward higher altitude; the others are unable to withstand the changing climatic condition and are enforced to die [41, 43].

3. Conclusion

The current velocity and magnitude of climate change trends will likely exceed the abilities of a number of species to survive and adapt to new environmental conditions thus leading to increased extinction rates. From an ecological point of view, climate velocity described as the speed and direction in which a species would need to move to sustain its current climate conditions under climate change. This is specifically true in Ethiopia because the current threat from habitat destruction, land use change or fragmentation, and rapid population growth interacts with climate change in a nonlinear way so that the negative impacts are higher than expected.

Biodiversity is vital for human wellbeing. However, its irreversible loss that entails the loss of ecosystem services and its multifunction is one of the most important environmental threats that humanity faces in the country. Climate change affects biodiversity in many. Impacts on species include changes in distribution and abundance, the timing of seasonal events and habitat use and, as a consequence there are likely to be changes in the composition of plant and animal communities. The current onset diversity composition change in Ethiopia is due to with climate change at large.

Recent climate change has become one of the main drivers of shifts in the geographical distributions of plant species. This is true for onset distribution in Ethiopia. There are several ways in which onset clones/landraces can respond to climate change: adapt, move in different directions in order to track suitable climates, (i.e. towards higher latitudes and elevations,

or to the east and west) and go extinct locally, regionally, or, in a worst case scenario, globally.

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