Review of literature on impact of climate change on plant biodiversity

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Abstract: Changes in the atmosphere and oceans can profoundly change the biosphere, the thin living film of life on Earth that is intrinsically coupled to the atmosphere and hydrosphere and provides the nourishing fabric within which human societies exist. Hence, degradation or restoration of parts of the biosphere are likely to have regional or planetary consequences. Anthropogenic greenhouse gas emissions, which drive both climate change and ocean acidification, increasingly threaten the viability and resilience of natural ecosystems, and the human societies that depend upon them. The effects of these threats can be profound and, in recent years, have become increasingly observable. Already, Earth is committed to a substantially warmed climate, with expectations of further warming into the future, unless carbon emissions trajectories change dramatically.
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Introduction:

Climate is defined as the weather condition of an area which are characterised by long term statistics for the methodological elements [1]. Whereas climate change means the change in climatic factors of an area caused due to the anthropogenic factors and natural disorders such as greenhouse effects and depletion of ozone layer [2]. In other words it involves temperature increase (global warming) sea level rise, change in precipitation pattern and increased frequencies of extreme events. Even change of one degree in mean global temperature over long period of time is sufficient to cause change of climate of an area and even the composition of many plant communities. The climate change (CC) though due to the alteration in external forces i. e natural factors or human activities, but future projections indicate the influence of only anthropogenic increase in greenhouse gases and other human related factors [3]. Therefore the twentieth century experienced the strongest warming trend of the last millennium with average temperature rising by about 0.6o c [4]. But temperature rise in future are likely to exceed this with a predicted rise between 0.1 and 0.2o c per decade. [5]. As far as India is concerned climate change is having a profound impact which is ranked fourth among the list of countries most affected by climate change in the period from 1996 to 2015 [6]. India emits about three gigatones of Carbon dioxide of green house gases each year and about two and half tones per person which is less than world average [7]. The country emits 7/of global emission [8].

The Forum examined several aspects of the latest science on how climate change affects terrestrial, freshwater and marine ecosystems, often in interaction with other factors. In particular, it explored current research frontiers including the effects of change in climate variability and extremes; interactions of climate change with other human-induced stressors; thresholds and the potential for abrupt and irreversible change; and multi-trophic interactions. Ecosystems are rapidly changing in response to climate change and other global change drivers, not only in response to temperature changes but also associated changes in precipitation, atmospheric carbon dioxide concentration, water balance, ocean chemistry, and the frequency and magnitude of extreme events. Ecosystems vary in their sensitivity and response to climate change because of complex interactions among organisms, disturbance and other stressors.

Changes in natural ecosystems threaten biodiversity worldwide, and have implications for global food production. The papers in this section advance our thinking about the effects of climate change on ecosystem properties (biological diversity, trophic webs or energy flux, nutrient cycling or material flux) in different ecological communities (terrestrial plants, invertebrates in marine sediments, terrestrial soil microbes).

In the opening paper of this section, Turner *et al*. [**6**] link climate variability and extremes to the potential for sudden and irreversible changes in ecosystems. Abrupt changes in ecological systems (ACES) are difficult to observe empirically because extreme events are, by their nature, stochastic and seldom predictable. Nonetheless, the authors urge scientists to make detecting, explaining and anticipating ACES in response to climate change a high priority. There is no 'new normal' (equilibrium), rather we are beginning to witness accelerating rates of change in the intensity and frequency of specific drivers. The study identifies important generalities that lead to questions and hypotheses for future research. These are: some dimensions of ecological systems are more prone to abrupt change than others; climate extremes may be more likely than mean trends to trigger abrupt change (e.g. coral bleaching is driven by extreme heatwaves rather than gradual ocean warming); multiple drivers often interact to produce ACES (e.g. climate change-driven drought and extreme fire can lead to abrupt changes of terrestrial ecosystems from forest to non-forest, introduced pathogens in combination with climate can cause populations of sensitive species to crash); historical contingencies (ecological legacies, frequency and order of disturbance, spatial context) are important drivers of ACES owing to ecosystem memory; and strong positive feedbacks in an ecosystem can sometimes lead to persistent state changes at critical transitions (tipping points).

Climate extremes and historical contingencies are also considered by Bardgett and Caruso [**7**], who synthesize current understanding of the attributes of belowground ecological communities that make them resistant, resilient or vulnerable to climate extremes. Soil microbial communities play a critical role in mediating biogeochemical cycling. Key intrinsic attributes of these communities that confer resilience include life-history strategy (growth rate, resource use efficiency) and microbial food web diversity (fast and slow energy channels found in bacterial versus fungal food webs). Fast energy channels (e.g. bacteria in a soil context) rapidly recycle nutrients and recover quickly from disturbances, hence providing resilience to change, whereas slow energy channels (e.g. fungi) cycle nutrients slowly, dampen responses to perturbations and hence confer resistance to change. The complementary functions of these two energy channels can facilitate rapid yet stable recovery from perturbations, and, conversely, alteration of the relative influence of these channels can destabilize an ecosystem. Extrinsic attributes include environmental variability, and the contributions that the plant community make to soil carbon, moisture and nutrients. While the response of belowground communities under chronic stress is fairly well understood, the authors identify response to climate extremes, and potential for abrupt ecological change, as critical knowledge gaps that should be addressed experimentally.

Resilience in ecological communities requires longer-term perspectives to improve our understanding of community responses to change. Iglesias and Whitlock [**8**] use palaeoenvironmental records of pollen and charcoal from temperate forests in the Northern and Southern Hemispheres to consider the role of fire in changing forest tree species composition. They find that the resilience or vulnerability of forest species composition to changing fire regimes depends on a variety of local factors, including climate, soil conditions and historical legacies; in some cases, extreme events, combined with biophysical feedbacks, can cause ecosystems made up of long-lived species to completely shift in ecosystem composition in response to a single fire event. Temperate forests have undergone both long periods of stability and abrupt change in response to climate change and human activities (burning for land clearing) during the Late Quaternary, and a site-specific understanding of stability versus disequilibrium is needed to anticipate future ecological scenarios under rates of warming that are unprecedented in the Holocene and beyond.

Climate change ultimately drives terrestrial biodiversity loss and affects ecosystem carbon storage both directly and indirectly via land use change, i.e. climate change-driven cropland expansion. Molotoks *et al*. [**9**] use a modelling approach to explore uncertainties in projections of biodiversity and carbon loss and find that, in spite of large uncertainties associated with land use projections, future cropland expansion is likely to have negative impacts on biodiversity and carbon storage in many biodiversity hotspots, including Mexico, Amazonia and the Congo Basin. This work highlights the importance of including indirect effects via changes in land use when assessing the total biodiversity and carbon impacts of climate change.

We close this section of the thematic issue with a thought-provoking essay by Harrison [**10**], which predicts that terrestrial plant community diversity will be eroded more than it is enhanced by climate warming, and calls for experimental work to test this prediction. She warns that current evidence suggesting climate warming might generally enhance diversity in temperate latitudes may not be generalizable because a preponderance of studies has occurred in the particular and unusual context of north-temperate alpine ecosystems. She predicts that net loss of diversity will predominate in water-limited ecosystems; losses will also occur in temperature-limited systems without steep topographical gradients where pools of potential replacement species are not found nearby.

Review of Literature:

Climate change is a major global threat that has already had an observed impact on biodiversity and natural ecosystems. Over the last century, the global average temperatures have risen by 0.7ºC and are predicted to continue rising. The Intergovernmental Panel on Climate Change (IPCC) predicts that temperatures are expected to rise by 1.1–6.4ºC by the end of the twenty-first century relative to the 1980–1999 baseline (IPCC 2013). Global average precipitations have increased by 2% in the last 100 years and are likely to increase in future (IPCC 2013). Africa is a highly vulnerable continent in the world to climate change. Overall, the continent has warmed 0.7°C over the twentieth century and warming across Africa is expected to continue with an increase ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario) (Hulme et al. 2001; IPCC 2001). Precipitation patterns in Africa are also more variable; however, historical records indicate that there has been an increase in rainfall over the last century in east and central Africa (Hulme et al. 2001; Intergovernmental Panel on Climate Change (IPCC) 2001). In addition to the changes in climate and weather, climate change in Africa is also linked to changes in the frequency and intensity of extreme events such as episodes of El Niño–Southern Oscillation (ENSO), that is, El Niño and La Niña (Korcha and Sorteberg 2013; Midgley and Bond 2015). As climate change is expected to increase over the next century, it is expected to become one of the major drivers for the loss of African biodiversity (Sala et al. 2000; Bellard et al. 2012; Midgley and Bond 2015). Thus, it is important to understand the link between biodiversity, ecosystem services, and climate change.

Africa is immensely rich in biodiversity and contains an estimate of one-fifth of all known species of mammals, birds, and plants, as well as one-sixth of herpers (Siegfried 1989). The content's species compose the world's most diverse and biologically important ecosystems such as savannahs, tropical forests, coral reef, marine and freshwater habitats, wetlands, and montane ecosystems. These regionally important ecosystems provide benefits that many African communities obtain, collectively known as ecosystem services (MA 2005). The African ecosystem supplies multiple ecosystem services required to meet human needs and sustain livelihoods including provisioning (e.g., feed, fuel-wood, food, timber), regulating (e.g., disease and climate regulation), supporting (e.g., soil formation, nutrient retention), and cultural (e.g., recreation, ecotourism) services (Millennium Ecosystem Assessment (MA) 2005, Wangai, Burkhard, and Muller 2016). However, these biodiversity, ecosystem, and ecosystem services are threatened due to climate change.

Climate change is both a cause and an effect of biodiversity and ecosystem change in Africa (Thomas et al. 2004). Along with anthropogenic stressors, the multiple components of climate change are anticipated to be the main drivers of biodiversity at all levels (Parmesan 2006). Loss of biodiversity due to climate change have directly or indirectly changed the pattern and dynamics of energy flow and material circulation (Zhong and Wang 2017), which greatly impacts the African ecosystem and ecosystem service. For instance, the capacity of ecosystems to provide climate regulation service depends on the diversity of species they currently support (Bellard et al. 2012). Climate change is also a consequence of the way in which biological resources are converted into useful goods and services, and especially of the way in which grasslands and forests are converted into croplands (Lambin and Meyfroidt 2011). The production of biological resources for foods, fuels and fibers, and the conversion of forests and grasslands for agriculture both directly affect emissions of several greenhouse gases (GHGs) (Hector and Bagchi 2007, 2007; Burnham and Ma 2015). Changes in stocks of biomass can also influence the amount of carbon sequestered (Hector and Bagchi 2007). It follows that options for the mitigation of climate change include the management of both GHG emissions from productive processes and carbon sequestration, while options for adaptation to climate change include the management of biodiversity for ecosystem resilience (Eric, Lambina, and Patrick 2011; Banin et al.2014; Araos, Berrang-Ford, and Ford et al. 2016). As African climate continues to change, there seems a consequence for biodiversity loss. These resulting effects bring changes on the range and distribution pattern of ecosystem and ecosystem services upon which human populations depend (Figure 1). However, there is limited understanding of the impact of climate change on multiple component of African biodiversity, and their functional or interactive role in ecosystem integrity and stability, how the system will respond to biodiversity loss induced by climate change, and ultimately affect the societal benefits they support. Thus, this comprehensive synthesis considers the connection between climate, biodiversity, and biodiversity-based ecosystem services in Africa. Here, I used information gleaned from different studies and databases to show the status and identify biodiversity and biodiversity-based ecosystem services that have been and will continue to be affected by climate change and their impending impact on human well-being in Africa. The impact of climate change on the well-being of human is described in terms the change in ecosystem services caused by climate-induced change in biodiversity. In this review, the categories of ecosystem services are those applied in the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment (MA) 2005).

Biodiversity loss

Globally, biodiversity is being lost and increasingly threatened through a range of anthropogenic actions (Jetz, Wilcove, and Dobson 2007; Bellard et al. 2012; Fardila et al. 2017; Barlow et al. 2018). The Convention of Biological Diversity (CBD) defines “biodiversity loss” as “the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services, to be measured at global, regional and national levels” (CBD COP VII/30). Fossil records showed that it took on average one million years before an individual vertebrate species became extinct (Lawton and May 1995). Hence, no more than one out of one million species should go extinct. However, the current observed extinction rate is 2.6 vertebrate species per 10,000 per year (Pimm and Raven 2006; Whiteside and Ward 2011). 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 (Brook, Sodhi, and Bradshaw 2008; Guo, Desmet, and Powrie 2017; Sonwa et al. 2017). As mentioned in the IPCC (2013) report, global warming and precipitation is expected to increase, the changing climate is predicted to be one of the worst drivers for the loss of all level of biodiversity over the next 50–100 years, and further exaggerated the effects of earlier threats on biodiversity loss. However, only few studies have directly quantified climate-induced biodiversity extinctions. Even if it is difficult to disentangle the impacts of climate change from other anthropogenic stressors for a range of species, consequently, predictions may provide insights into the multiple components of climate change and their relative distribution threats to global biodiversity (IUCN 2014; Trull, Böhm, and Carr 2018). 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 (He and Hubbell 2011; Mora et al. 2011). For instance, Monzón et al. (2011) 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 (IUCN 2016). 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 (Keith et al. 2008; Loarie et al. 2009; Bellard et al. 2012). 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 (Brito-Morales et al. 2018). This is specifically true in Africa 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

(Midgley et al. 2002; Sonwa et al. 2017; Barlow et al. 2018).

Effects of climate change on biodiversity

Africa boasts remarkable biodiversity, including the many endemic and endangered mammals and plants. However, species abundance and diversity is in decline and the threats to species diversity are increasing. Climate change is one of the major threats to biodiversity and ecosystem services in the region (Lepetz et al. 2009; Guo, Desmet, and Powrie 2017; Sonwa et al. 2017; Matata and Adan 2018). The United Nations Framework Convention on Climate Change and the CBD recognize that climate change is one of the greatest threats to biodiversity. Recent studies also have shown the impacts of climate change on biodiversity in Africa. For instance, Midgley et al. (2002) studying the potential impact of climate change on plant diversity in the Cape Floristic Region in South Africa have shown that 11% of the species studied are at risk of extinction, and a reduction in the modeled range sizes of 42% of the species, with the projected climate-change scenario. A study published in *Nature* (Thomas et al. 2004) reveals that climate change could result in the extinction of more than a million terrestrial species in the next 50 years. Rare species, fragmented ecosystems, and areas already under pressure from pollution and deforestation are the most vulnerable. Fire is a major cause of biodiversity loss in Africa. As global warming increases, these fires are likely to get more intense and extensive and may result in significant ecosystem changes that would affect biodiversity through species loss or changes in species composition (Bellard et al. 2012; Foden et al. 2013; Akcakaya et al. 2014; Bland et al. 2015; Pacifici et al. 2015). Similarly, the broad conclusions of the review outputs showed that direct and indirect effects of climate change have posed potential major threats to biodiversity in Africa.

Direct effects include those arising from increased temperature and increased CO_2 levels associated with global climate change (Adler, Leiker, and Levine 2009; Andrew et al. 2010; Dawson et al. 2011). These direct effects result in several potentially major indirect effects, such as changes in hydrologic cycles (evaporation and precipitation) and an increasing magnitude and extent of extreme weather events and frequent fires that destroy the ecosystem. These changes can affect biodiversity in many ways, including altering life cycles, by shifting habitat ranges and species distribution, changes in abundance, changes in migration patterns, and changes in the frequency and severity of pest and disease outbreaks.

One of the other important pathways by which climate change affects African biodiversity is by reducing the amount and availability of suitable habitats and by eliminating species that are vital for the species in question (Lovett, Midgely, and Barnard 2005; Hély et al. 2006; Doak and Morris 2010; Dawson et al. 2011). A loss of species from an ecosystem not only affects the species that is lost but also the interactions with other species as well as the general ecological functions, which are expected from these interactions. Despite growing awareness that biodiversity is one of the most vulnerable to climate change, Africa is one of the least studied region in terms of biodiversity dynamics and climate variability (Getahun and Shefine 2015; Sonwa et al. 2017; Matata and Adan 2018). Therefore, understanding how climate change affects African biodiversity is important, both for examining status or trends, responses, and identifying biodiversity that are sensitive to climate change system and to provide valuable insights to avoid or mitigate climate-induced effects.

Conclusion

According to the IPCC's 4th report India is going to be badly affected by the climate change. As biodiversity is one of the main component / pillar for our survival and sustenance and is going to hit by the climate change. The impact on forest shall be negative on balance although some positive effects may be seen in the short run. Biodiversity which is already in constant threat due to developmental activities shall be further stressed by climate change and possibly half of the species shall disappear in next 50 years. Although biodiversity provides food for all life forms and used as primary health care for more than 60-80/ of worlds human population, it has been affected by human activities and climate change. Thus increase in temperature and carbon dioxide concentration level would have an impact on timing seasons of flora and fauna. Accordingly species ecosystem composition and function have been affected both directly and indirectly and as a result species have been shown a modification in their morphology, physiology, behavior and they are forced to migrate due to changes in climatic variables globally. There is wide scope of more research on forest productivity, behavior of different species and productivity under different climatic scenarios.

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