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Plant Species Diversity for Climate Change Adaptation and Mitigation

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ABSTRACT

Climate is one of the most important factors that influence and determine the behavior, abundance and distribution of species, as well as having a strong influence on the ecology of habitats and ecosystems structure. Changes in the behavior, abundance and distribution of species are linked to climate. Diversity and plant species are highly interlinked and the relationship between biodiversity and climate change should be explored from several perspectives. This variety provides the building blocks to adapt to changing environmental conditions which are caused due to climate change. Conserved habitats can remove carbon dioxide from the atmosphere, thus helping to address climate change by storing carbon in the plant biomass. Climate is one of the major limiting factors which determine the survival and growth of plants. The conservation and restoration of biodiversity and ecosystem services can play a key role in helping societies to adapt to climate change. Biodiversity is affected by climate change, but biodiversity, through the ecosystem services and function it supports, also makes an important contribution to both climate-change mitigation and adaptation. Maintenance of agro-biodiversity and carbon sequestration through the process of photosynthesis is the two important and complementary environmental services of agro-ecosystems. Climate change affects biodiversity and one of the causes of biodiversity loss. At the same time climate change will accelerate further if biodiversity and ecosystems are not effectively protected. Generally due to the variation of genetic makeup within pants, different plant species diversity plays a great role in climate change adaption and mitigation process.

Keywords:
Adaptation, carbon, climate change, diversity, mitigation

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1. Introduction

Climate change is one of the hottest issues of the world and one of the most important factors which influences the behavior, abundance and distribution of species, as well as having a strong influence on the ecology and ecosystems. Diversity and plant species are highly interlinked and the relationship between biodiversity and climate change adaptation should be explored from several perspectives. As climate change increasingly puts a strain on ecosystems and species populations, it is important to find ways to increase their resilience to current and future climate change (Reid and Swiderska, 2008). At the same time, the conservation and restoration of biodiversity and ecosystem services can play a key role in helping societies to adapt to climate change. Biodiversity is affected by climate change, with negative consequences for human well-being, but biodiversity, through the ecosystem services and function it supports, also makes an important contribution to both climate-change mitigation and adaptation (UNEP, 2009). Consequently, conserving and sustainably managing biodiversity is critical to addressing climate change.

The main cause of climate change is the accumulation of Green House Gas (GHG) in the atmosphere. Among the GHG's this three gases, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) are the major gases, which contribute about 88% roles in global warming. Due to anthropogenic effect the concentration of CO_2, CH_4 and N_2O and other Green House Gas is increased in atmosphere in an alarming rate. From those GHG the concentration of CO_2 take a large percent in atmospheric accumulation (Parajuli, 2009). But huge carbon stored in the atmosphere is from the burning of fossil fuel and conversion of forest land into agricultural land through deforestation. Due to the accumulation of large amounts of carbon in the atmosphere, our world exposed to different problems like temperature fluctuation, drought, floods, landslides, land degradation, deforestation, loss of biodiversity, desertification, water and air pollution, different health problem and so on. So to reduce climate change impacts reducing the amount of CO_2 released into atmosphere and absorbing those released in the atmosphere through plant photosynthesis process is one solution.

Carbon sequestration is the process by which carbon dioxide is absorbed by green plants during photosynthetic process and is stored as carbon in plant biomass (trunks, branches, foliage, and roots) (Cook *et al.,* 2013). Plant species diversity is one of the determinate factor which affect atmospheric carbon capture and storage (Adair *et al*., 2009). Maintenance of agro-biodiversity and carbon sequestration through the process of photosynthesis is the two important and complementary environmental service functions of agro-ecosystems. While C sequestration in the biosphere is seen as an option to mitigate climate change (Houghton *et al.,* 1993). The purpose of this paper is to review the relationship of plant species diversity and climate change, and assess the implication of plant species diversity on climate change adaptation and mitigation.

2. Concept and Definition of Terms

2.1. Biodiversity

According to the Convention on Biological Diversity (CBD) biodiversity has been defined as: "the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems" (CBD, 2009). In short, biodiversity refers to the variety of life on earth. This variety provides the building blocks to adapt to changing environmental conditions which are caused due to climate change. Biodiversity provide different services both for human being as well as for the environment. These services include clean water, pure air, soil formation and protection, pollination, crop pest control, and the provision of foods, fuel, fibers and drugs. Reduction in biodiversity affects these ecosystem services (IBC, 2005).

2.2. Climate Change

Climate is can be defined as the expected weather conditions at a given location over time (UNEP, 2008). It is the typical characteristics of one particular geographic area which determine the type of plant and animals that live and adapt there and the living system of a particular place. Climate change is a long-term shift in the climate of a specific location, region or planet (UNEP, 2013). The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation. Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period of time, typically decades or longer.

Climate change is one of the major challenges of our time and a big stress to our societies and to the environment. From shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding. Due to its nature the impacts of climate change are global in scope. Without drastic action today, adapting to these impacts in the future will be more difficult and costly (UNEP, 2013). Climate can be changed due to different natural and human induced problems. Some of the natural process can be volcanic eruptions, variations in the sun's intensity, or very slow changes in ocean circulation or land surfaces which occur on time scales of decades, centuries or longer. The most common human induced climate changes are releasing greenhouse gases and aerosols into the atmosphere, deforestation, and by depleting the stratospheric ozone layer.

2.2.1. Climate Change Adaptation

According to Spittle house and Stewart (2003) adaptation is defined as the adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. It is a key component of coping with climate change. In addition to this according to IPCC, adaptation can be defined as the ‘’adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities’ (IPCC, 2007). The general aim of adaption is to reduce the vulnerability or enhance resilience in response to these actual or expected changes and associated extreme events, and will be required in both human and ecological systems (Adger *et al.,* 2007).

Adaptation can significantly reduce adverse impacts of climate change and an important part of societal response to global climate change. Adaptation to climate change has the potential to substantially reduce many of the adverse impacts of climate change on the human being as well in the environment, and enhance beneficial impacts. This is in contrast to changes in behavior to reduce greenhouse gas emissions or try to prevent or reduce further changes in climate. The term adaptation covers many activities that can be classified in several ways (e.g., by timing, leads, type, and social scale categories) (Becken, 2005). Adaptation is a process by which strategies aiming to moderate, cope with, and take advantage of the consequences of climate events are enhanced, developed and implemented.

2.2.2. Climate Change Mitigation

Climate mitigation is any action taken to permanently eliminate or reduce the long-term risk and hazards of climate change to human life, property. The International Panel on Climate Change (IPCC) defines mitigation as: “An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.” (UNEP, 2008). Climate change mitigation is actions to limit the magnitude and/or rate of long-term climate change. Climate change mitigation generally involves reductions in human (anthropogenic) emissions of green house gases (GHGs). Mitigation may also be achieved by increasing the capacity of carbon sinks, e.g., through reforestation (IPCC, 2007). Climate Change mitigation refers to efforts to reduce or prevent emission of greenhouse gases. Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behavior. It includes technological, economic and social changes and substitutions that can help to achieve reductions in greenhouse gas emissions (Hall and Williams, 2008).

Climate change mitigation activities seeks a net reduction of greenhouse gas emissions, and also concerns the protection and promotion of carbon sinks, through land use and habitat management which enhances carbon sequestrations in different systems. Even if mitigation activities are under taken under different local levels, it has a global benefit which helps all worlds through carbon emission reduction from the atmosphere (Adger *et al.,* 2007)

3. Climate Change and Biodiversity

3.1. Impact of Climate Change on Biodiversity

Biodiversity and climate change are the two interlinked phenomena which are positively or negatively affect each other. Climate is one of the most important factors that influence and determine the behavior, abundance and distribution of species, as well as having a strong influence on the ecology of habitats and ecosystems structure. Changes in the behavior, abundance and distribution of species are already being observed and linked to environmental climate. The direct impacts of climate change on plant biodiversity will occur through two anthropogenic effects; warming, which lengthens the period of activity and increases plant productivity, and the reduction in water availability (IPCC, 2002).

Based on different evidences we know that climate change affects biodiversity. According to the Millennium Ecosystem Assessment, climate change is one of the most significant drivers of biodiversity loss. Climate change is already forcing biodiversity to adapt either through shifting habitat, changing life cycles, or the development of new physical traits. Conserving natural terrestrial, freshwater and marine ecosystems and restoring degraded ecosystems (including their genetic and species diversity) is essential. Because ecosystems play a key role in the global carbon cycle and in adapting to climate change, while also providing a wide range of ecosystem services that are essential for human well-being and the achievement of the Millennium Development Goals.

Biodiversity play a great role in the process of reducing negative effects of climate change. Conserved or restored habitats can remove carbon dioxide from the atmosphere, thus helping to address climate change by storing carbon in the plant biomass (DEFRA, 2008). Climate is one of the major limiting factors which affect or determine the survival and growth of plants. Every plants has its location were grow and adapt well. Even if the growing place of plant are vary depends on the type of species, every plants needs suitable climatic condition to survive and grow. But when this climatic condition is vary from the normal condition the plants are shocked and develop adaption mechanism for the changed environments. For this climate change problem plants give response for its adaption mechanism. There are a number of direct impacts of climate change upon biodiversity have been identified from observational data (Hopkins *et al.,* 2007).

Some of the most common response of plants to climate change is; changes in the timings of seasonal events, leading to loss of synchrony between species and the availability of food, and other resources upon which they depend (*Phenology),* shifts in suitable climate conditions for individual species leading to change in abundance and range (*Species abundance),* changes in the habitats which species occupy (*Range changes)* and changes to the composition of plant communities (*Habitat preference).* Changes to habitats and ecosystems, such as altered water regimes, increased rates of decomposition in bogs and higher growth rates in forests (*Ecosystem function).*

3.2. Biodiversity Effects on Ecosystem Functioning

Ecosystem functioning reflects the collective life activities of plants, animals, and microbes and the effects these activities; feeding, growing, moving, excreting waste, etc. have on the physical and chemical conditions of their physical environment. A functioning ecosystem is one that exhibits biological and chemical activities characteristic for its type. Ecosystem functioning results from interactions among and within different levels of the biota, which ecologists describe as a nested hierarchy (Nessa and Tasman, 2005). The efficiency of ecosystem processes is depends on which species are present at a particular place. In the presence of a species that is very effective in driving a particular process, the performance of the system with respect to this process will be high. Critical processes at the ecosystem level is influence plant productivity, soil fertility, water quality, atmospheric chemistry, and many other local and global environmental conditions that ultimately affect human welfare. These ecosystem processes are controlled by both the diversity and identity of the plant, animal, and microbial species living within a community (Hooper and Vitousek, 1997). Understanding the relationship between biodiversity and ecosystem functioning is of great theoretical interest for understanding the processes structuring communities, and of practical importance to predict the effect of human induced biodiversity loss. Numerous experiments have demonstrated that a range of ecosystem functions depend on biodiversity (Tilman *et al.,* 2001).

The interactions between carbon, nutrient and water cycles are fundamental to ecosystem functioning and it is important to know whether they are affected differently by biodiversity loss. Loss of biodiversity has reduce biomass production (Marquard *et al.,* 2009), and affect other pools and fluxes of the carbon (Steinbeiss *et al.,* 2008) and nitrogen cycle (Oelmann *et al.,* 2011). A relationship between plant biomass production and nutrient uptake would be expected in ecosystems strongly limited by nutrients where resource use complimentarily for nutrients may be the dominant mechanism driving the species richness-biomass relationship (Tilman *et al.,* 2001). Due to the great interaction climate change will have significant effects on species and ecosystems, and influence most aspects of our society.

According to Millennium Ecosystem Assessment (2005) report the most common ecosystem services provided through biodiversity are:

- **Supporting Services** (services that maintain the conditions for life on earth): Soil formation and retention; nutrient cycling; primary production; pollination and seed dispersal; production of oxygen; provision of habitat.
- **Regulating Services** (benefits obtained from regulation of ecosystem processes): Air quality maintenance, climate regulation, water regulation, flood control, erosion control, water purification, waste treatment, detoxification, human disease control, biological control of agriculture and livestock pest and disease, storm protection.
- **Provisioning Services** (products obtained from ecosystems): Food, wood fuel, fiber, biochemical's, natural medicines, pharmaceuticals, genetic resources, ornamental resources, fresh water, minerals, sand and other non-living resources.
- **Cultural Services** (non-material benefits obtained from ecosystems): Cultural diversity and identity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage,

recreation and ecotourism, communal, symbolic.

4. Climate Change Adaptation and Mitigation Options with Biodiversity

4.1. Biodiversity and Climate Change Adaptation

Climate change is having a strong impact on biological systems through changes in species populations, communities and ecosystem processes, with potential consequences for future ecosystem provision. The effect of recent climate change is already evident at the level of species abundance and distribution, with many species throughout the world shifting their latitudinal and altitudinal ranges consistent with the recorded warming environmental temperature. These range changes caused colonization and extinction events that have resulted in changes in the diversity and composition of communities (Preston *et al.,* 2008).The relative abundance of species within communities is also changing, with increasing dominance by newly arriving species and species with broad ecological niches at the expense of species with narrow environmental requirements. In addition, phenological changes in plant species in response to climate change are widely observed (Montoya and Raffaelli, 2010).

Climate change adaptation activities are one of the processes which are used to reduce the impacts of climate change on human wellbeing as well as on the physical environment. Depending on the way in which such strategies are implemented, some climate change adaptation activities may have either beneficial or adverse impacts on biodiversity. In terms of negative impacts, a loss of biodiversity due to adaptation measures may impair ecosystem functions, resulting in increased vulnerability to future climate change. If we see other example the use of pesticides and herbicides may be increased to control new pest and diseases, and invasive alien species that might result from climate change (Campbell *et al.,* 2009). This may lead to damage to existing plant and animal communities, water quality, and human health.

Biodiversity is linked to climate change adaptation in three main ways;

1. Biodiversity can play a role in societal adaptation
2. Biodiversity can be impacted by societal adaptation strategies, and
3. Biodiversity conservation is a sector that requires adaptation strategies in its own right

Plant species which is venerable to climate change is developing adaptive mechanism to reduce the impact of climate change. This mechanism helps plant species in order to live in or shift from in changing environment. Species may be able to adapt autonomously to climate change by: dispersing to suitable habitats, changing their phenotype without a change in genotype via phenotypic plasticity or adapting by genetic change over generations (evolutionary response)

The first two responses may occur rapidly, and have been observed more frequently than the latter as responses to recent climate change (Kapos *et al.,* 2008).

4.2. Biodiversity and Climate Change Mitigation

Biodiversity play a major role in each climate change mitigation activities. Mitigation activities that use the ecosystem approach to incorporate biodiversity considerations can potentially have lower risk of failure (Thompson *et al.,* 2003). Mitigation activities include emission avoidance activities and carbon sequestration activities. In terrestrial systems, mitigation activities accumulate carbon both in above and belowground. In old growth forests carbon continues to accumulate in the soil and vegetation, and especially where decomposition is slow, carbon stores can be maintained for long periods of time (Paul *et al.,* 2003).

According to Travis and Daniel (2012) the core challenge of climate change adaptation and mitigation in agriculture is to produce more and sufficient food, more efficiently, under more volatile production conditions, and with net reductions in GHG emissions from food production and marketing process. In addition to increasing productivity generally, several new varieties and traits offer farmers greater flexibility in adapting to climate change, including traits (varieties) that confer tolerance to drought and heat, tolerance to salinity (e.g., due to rising sea levels in coastal areas), and early maturation in order to shorten the growing season and reduce farmers' exposure to risk of extreme weather events.

Since land use changes, including deforestation and conversion to agricultural production account for 17% of global CO_2 emissions (World Bank, 2009), productivity gains represent a significant mitigation mechanism in agriculture. New varieties and traits can also lead to less intensive use of other inputs such as fertilizers and pesticides and the associated equipment which are great contribution for GHG's emission.

5. Carbon Storage and Biodiversity

5.1. Plant Species Diversity and Carbon Sequestration

Due to high species diversity tropical regions it contributes a significant role in terrestrial carbon storage. One of the carbon storage methods is storing in plant as plant biomass. Depends on the characters of different plant species the amount of carbon stored in biomass is vary from one species to the other. The significant amount of carbon stored in plant biomass is the one which are stored the perennial type plants species. The age and the amount of biomass production of vary between different species. Due to this direct relation ship carbon storage and plant species diversity has highly interlinked. Even the amount of carbon stored in soil is affected by the plant species which are grown in land.

Dominant plant species strongly influence the size and turnover rate of the aboveground carbon stocks. They are also a primary determinant of the size and turnover rate of soil carbon stocks by determining the quantity and quality of resources that they return to the soil. In productive and fertile ecosystems, plant production (i.e. carbon input) is greater, but plant litter quality and soil activity (litter decomposition rates, i.e. carbon loss) are also greater as compared to unproductive ecosystems. Generally productive ecosystems have a greater input of carbon and may sometimes store more carbon aboveground, they often also store much less carbon in the soil, and also less carbon overall. The composition of plant species and genotype mixtures, and in some cases their richness and spatial arrangement, can significantly influence stand-level properties such as the amount of biomass production , its stability, nutrient use efficiency , soil organic matter quantity and quality, litter decomposition , and susceptibility to pest outbreaks. The identity, the relative abundance, the number, and the spatial arrangement of species are in principle all likely to have an impact on carbon sequestration (DıˊAz *et al.,* 2009). In agro ecosystems, although organic C stocks in the soil represent often the largest C sink (Dixon, 1995), aboveground biodiversity may still impacts on belowground C sequestration (e.g., through litter fall, root exudation and turnover or soil erosion control). Agro ecosystems with a broader diversity of plant species, living forms and production activities may achieve higher levels of productivity in the long-term while maintaining larger and more stable C stocks (Yachi and Loreau, 1999).

5.1.1. Carbon Sequestration in Natural Forest

Forest has a capacity to sequester carbon in their biomass and play a significant part of the global carbon cycle. The world's forests are prominent sites to study of climate change, not only in terms of total net carbon emissions but also in terms of global storage capacity, important for climatic regulation. Carbon dioxide is absorbed by trees, plants and crops through photosynthesis and stored as carbon in biomass in tree trunks, branches, foliage and roots and soils (EPA, 2008). Natural forest is also one of the most common terrestrial ecosystems which contain different types of plant species diversity. This ecosystem is contributing the major role in regulating global carbon in their biomass. Also natural forest ecosystem is the undisturbed ecosystems which are contain different matured and long aged trees which have a capacity to sequester carbon in their biomass for a longer period of time. Natural forest is one of the most known ecosystems for the long term carbon sequestration due to the capacity forest to sequester carbon in their biomass. In addition to the species density, species diversity is known character of natural forest which has a great implication in carbon storage (Ruiz-Jaen and Potvin, 2010). FRA (2010) estimated that the world's forests store 289 Gt of carbon in their biomass alone. Due to close relationship between C stocks and biodiversity, tropical forests carbon storage depends largely on plant species composition (Bunker *et al.,* 2005).

Carbon sequestration describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming and avoid serious climate change. There are two alternatives to reduce atmospheric CO_2; decreasing carbon source and increasing carbon sink. Therefore forests are key components of the effort to reduce emissions because trees absorb carbon dioxide as they grow; lowering levels of greenhouses gases in the atmosphere. Irrespective to the management interest, shifting a land to a forest area results in increment of carbon dioxide sequestration, both belowground and above ground (Albrecht and Kandji, 2003). One study in China revealed that aboveground C stocks increased at a rate of 2.75 Mg C ha^{-1} yr^{-1} in the poplar plantations, and 1.06 Mg C ha^{-1} yr^{-1} in the Mongolian pine plantations (Hu *et al.,* 2008).

In case of forest carbon sequestration plant species diversity is one of the limiting factors which determine the amount of carbon stored in the system. Due to morphological and age variation different plant species have different storage capacity. The amount of carbon stored in the forest is varying by a type of forest. For example due to high species diversity moist tropical forests sequestration nearly 110 tons of carbon per acre, temperate forests contain carbon averaging nearly 70 tons per acre, and boreal forests generally contain more carbon than temperate or tropical forests, averaging more than 180 tons per acre (Cabe, 2009). In Ethiopia also there are large forest coverage and sequestered high amount of carbon on their biomass. Forests play an important role in the global carbon balance and used as both carbon sources and sinks. They have the potential to form an important component in efforts to combat global climate change. According to Yetabitu *et. al.* (2010) the carbon storage capacity of Ethiopia forest is estimated to be 2.7billion tons of carbon. The research results indicate that the forest resources of Ethiopia sequester 44 times the amount of CO_2 that is being released by burning the woody biomass stocks as fuels and 478 times the CO_2 released from clearing forests for agriculture.

5.1.2. Carbon Sequestration in Agroforestry Practices

Agroforestry is one of the land use system which include different components. From those components vegetations which are different crops (annual and perennial) and trees are important components which play a great role in carbon storage. Due to the diversification of vegetations, this system has higher carbon stocks potential than other agricultural monocultures. Due to this factors expansion of agroforestry practices could raise the carbon stocks of Africa's terrestrial systems (Albrecht and Kandji, 2003). According to Dixon *et al.* (1994) globally the estimated sequestration potential by forestry and agroforestry practices is about 1Pg of C per year, corresponding to about 3.7 Pg CO_2, or roughly one-eighth of annual global emissions. Carbon stored by tree component in agroforestry is well pronounced even though it depends on type of species, density and management practices. More treeorigin C was found in larger particle size and surface soil and indicated that long-term tree presence promoted storage of protected C in deeper soil (David *et al.,* 2011). Agroforests including homegarden is well known in sequestrating much more C than other agroforestry practices. The multi-strata and the high diversity characteristics allow them to efficiently use light and nutrients. With this regard, high biomass accumulation is formed (Schorth *et al.,* 2002). Agroforestry systems such as parklands, live fences, and homegarden had accumulated 0.2 – 0.8 Mg C ha^{-1} $year^{-1}$. Rotational woodlots (2.2–5.8Mg C ha^{-1} $year^{-1}$) and possibly improved fallows in Southern Africa sequestered C relatively faster.

Agro ecosystems with a broader diversity of plant species, living forms and production activities may achieve higher levels of productivity in the long-term while maintaining larger and more stable C stocks (Yachi and Loreau, 1999). Due to high plant species diversity, agro-forestry systems stand have larger chances to sequester C in the long-term than annual cropping systems, adding aboveground C storage capacity through a broader diversity of living forms, including fruit or timber trees, perennial crops and potential fertilizer and fodder trees. Albrecht and Kandji (2003) estimated a potential C sequestration in tropical agroforestry systems of 95t C ha^{-1} (varying widely between 12 and 228t C ha^{-1}).

6. Conclusion

Climate change is one of the current hottest issues which affect every part of the world. Therefore in order to overcome the effects of climate change plants play different role through adaption and mitigation process. Those are; adapting and sustain their life in the natural ecosystem, changing their geographical range, changing their growing pattern, different plant varieties are have the capacity to resist the pests and disease which are occur due to climate change/variability, regulating the surrounding temperature, sequestering CO_2 in there biomass which are the major GHG and incurring additional income through carbon finance. Generally due to the variation of genetic makeup within plants, different plant species diversity plays a great role in climate change adaption and mitigation process through reducing greenhouse gas emissions and increasing biological and geological sequestration of carbon, reducing the negative effects of climate change by using adaptive management, strategic planning, and site-specific management tools and techniques (e.g., wetland protection or remediation) and helping people to adapt to changes in climate through economic diversification.

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