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The Role of Biodiversity in Adaptation to Climate Change: A Review

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ABSTRACT

Biodiversity and well-functioning ecosystems provide natural solutions that foster resilience, thereby assisting society in adapting to the negative effects of climate change. Through conducting a thorough review on maintaining and restoring native ecosystems, agrobiodiversity, landscape connectivity, and protected areas, this project aims to achieve its objective. Biodiversity is the variety of all living organisms on the planet. To examine the role of biodiversity in climate change adaptation, 55 distinct sources, including 50 peer-reviewed publications and 5 books, were utilized. The current analysis identifies sustainable management of biodiversity as an essential climate change adaptation strategy because species and genetically diverse ecosystems have a greater capacity to adjust to climate change. Furthermore, such measures boost the climate change resilience of ecosystems. So that they can continue to provide ecosystem services, hence facilitating the supply of alternate means of subsistence in the face of climate change. Many of these studies assume that biodiversity and climate change are tightly interconnected due to their mutual impacts. For instance, human-induced climate change poses a threat to biodiversity, but biodiversity resources can mitigate the effects of climate change on populations and ecosystems. However, a large number of research also point to context-dependent adaptation techniques that can be either positive or harmful depending on the circumstances. The majority of research has been undertaken on the poorest or most vulnerable households, with a primary focus on small islands and mountains, whereas other ecosystem products have been mostly neglected. Consequently, an essential strategy for conserving biodiversity and human well-being entails measures that are kept flexible in order to better adapt human societies to climate change, as well as biodiversity education and training activities that are superior at distributing innovative techniques.

1. Introduction

Biodiversity is defined as the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems, as well as the ecological complexes of which they are a part; this includes diversity within species, between species, and among ecosystem (CBD, 2010) Biodiversity, which underpins ecosystem processes and properties, provides critical benefits to humans, such as supporting (e.g., nutrient cycling and primary production), provisioning (e.g., food, timber, fuel, and fresh water), regulating (e.g., climate and water regulation), and cultural (e.g., spiritual experience, recreation, and education) (MEA, 2005;Díaz *et al.*, 2006). As a result of the services that healthy ecosystems can provide, biodiversity can assist humans in adapting to the effects of climate change. Healthy ecosystems can better withstand the effects of climate change. A degraded ecosystem will most likely have less biodiversity, resulting in fewer species that can withstand the effects of climate change. The more species that live in an ecosystem, the better their chances of survival, ensuring that the ecosystem's functions (and the services we receive as a result) are preserved. (MEA, 2005).

Adaptation to climate change is the process of responding to and adjusting to actual or potential impacts of changing climate conditions in ways that mitigate harm and utilize on any positive opportunities. In other words, adaptation is the process by which people reduce the negative effects of climate variability on their health and wellbeing while also taking advantage of the opportunities provided by their climatic environment. (Smit *et al.*, 2000). Adaptation can be reactive or anticipatory (timing), autonomous or planned (spontaneity), and private or public (scale) (Smit *et al.*, 2000). Reactive or spontaneous adaptation occurs in response to climate change, whereas anticipatory adaptation occurs in anticipation of or in response to climate change (Biju Kumar & Ravinesh, 2017). Ecological changes in natural systems and market or welfare changes in human systems both trigger autonomous adaptation (IPCC, 2007a). Maladaptation is another term used to describe a situation in which a strategy unintentionally increases vulnerability. As a result, adaptation activities can have a positive impact on biodiversity by: preserving and restoring native ecosystems, Protecting and improving ecosystem services, actively preventing and controlling invasive alien species, managing habitats for rare, threatened, and endangered species, and developing agroforestry systems in transition zones between ecosystems are all priorities. Monitoring outcomes and adjusting management regimes as needed.

Climate variability and change are two of the most serious environmental challenges of the twenty-first century. The Intergovernmental Panel on Climate Change has issued several reports. (IPCC, 2007) and various other studies (Reid et al., 2005 ;Morton, 2007; Cooper *et al.*, 2009; Schlenker and Lobell, 2010; Thornton *et al.*, 2011) demonstrate that climate change is having a wide-ranging impact on human societies and the environment. Anthropogenic factors, according to scientific evidence, are the primary contributors to the current global climate change (Forster *et al.*, 2007). The concentration of greenhouse gases (GHGs) in the atmosphere, such as carbon dioxide, methane, and nitrous oxide, has steadily increased over time. Carbon dioxide concentrations, for example, have increased from 280 ppm (pre-industrial level) to around 394 ppm in 2012, a 41% increase (www.epa.gov/climatechange/indicators). The global average temperature has risen by 0.74 degrees Celsius in the last century and is expected to rise by 1.1 to 5.8 degrees Celsius by the end of this century, and rainfall patterns will change as the frequency of extreme events rises (Meehl *et al.*, 2007; IPCC, 2012).

Climate change and biodiversity are, however, inextricably linked: climate change has severe direct and indirect impacts on biodiversity and is predicted to be a major driver of future biodiversity loss; at the same time, biodiversity loss magnifies the negative effects of climate change. Other drivers of biodiversity loss include habitat degradation/destruction and the introduction of invasive alien species into ecosystems, but these threats will be amplified by the effects of climate change and are thus linked to the same issue. Similarly, biodiversity conservation and climate change mitigation are inextricably linked and interdependent. Managing and protecting biodiversity will help humans adapt to the negative effects of climate change; policies and actions aimed at limiting the effects of climate change will contribute to biodiversity protection (Jathar et al., 2014).

Furthermore, the role of biodiversity in climate change adaptation will become an increasingly important part of the development agenda, increasing ecosystems' ability to adapt to gradual or dramatic global shifts in environmental conditions (Hisano et al., 2018). Several billion people worldwide rely directly on biodiversity for their livelihoods through both natural and human-managed ecosystems. As a result, conserving natural terrestrial, freshwater, and marine ecosystems, as well as restoring degraded ecosystems (including their genetic and species diversity), is critical to the UNFCCC's overall goals, because ecosystems play a critical role in the global carbon cycle and in adapting to climate change, while also providing a wide range of ecosystem services critical to human well-being and the achievement of the Millennium Development Goals (SCBD, 2010). Similarly, the importance of healthy ecosystems in climate change adaptation is being recognized. Ecosystem-based Adaptation (EbA) is defined as the "integration of sustainable use of biodiversity and ecosystem services into an overall adaptation strategy that can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity. It entails the long-term management, conservation, and restoration of ecosystems in order to provide services that assist people in adapting to the negative effects of climate change (CBD, 2009). Conservation of ecosystem structure and function, on the other hand, is an important climate change adaptation strategy because species and genetically diverse ecosystems have a greater ability to adapt to climate change. While some natural pest-control, pollination, soil-stabilization, flood-control, water purification, and seed-dispersal services can be replaced when damaged or destroyed by climate change, technical alternatives may be prohibitively expensive in many cases (Tscharntke et al., 2012). Conserving biodiversity (for example, genetic diversity of food crops, trees, and livestock races) means that options for better adapting human societies to climate change are kept open (Braatz, 2012).

The overarching goal of this paper is to show how a landscape ecology approach has resulted in a broader and more integrative understanding of natural processes in European river corridors by elucidating the strong links between spatiotemporal heterogeneity and hydrodynamic processes, including interactions between surface and ground waters. The overarching goal of this paper is to show how a landscape ecology approach has resulted in a broader and more integrative understanding of natural processes in European river corridors by elucidating the strong links between spatiotemporal heterogeneity and hydrodynamic processes, including interactions between surface and ground waters. The overarching goal of this paper is to show how a landscape ecology approach has resulted in a broader and more integrative understanding of natural processes in European river corridors by elucidating the strong links between spatiotemporal heterogeneity and hydrodynamic processes, including interactions between surface and ground waters.

As a result, the primary goals of this review paper are to demonstrate the role of biodiversity in climate change adaptation that is currently being implemented around the world, as well as to assess their effectiveness in climate change adaptation.

The review's scope was limited to studies that correlated the role of biodiversity with variables that can be meaningfully related to climate change adaptation. Secondary data sources were used to collect, interpret, and evaluate the information presented here. Various authors and researchers have written about biodiversity and climate change; government and non-government organizations have produced reports on the role of biodiversity in the world's adaptation to climate change. To stimulate debate and discussion within the conservation community, I wanted to first describe some of the various strategies being used to integrate climate change adaptation into the role of biodiversity (with some examples). Finally, the most relevant peer-reviewed journals and books were reviewed, and their key findings were extracted and presented in the paper. Finally, by conducting this review, I discovered a number of different strategies that appear to be important in effective climate change adaptation.

2. Discussion

2.1 Definitions and concepts of biodiversity, adaptation and climate change

Biodiversity is more than just the number of species on the planet; it also includes genetic variability within and between populations, species' evolutionary histories, and other indicators of life's diversity (Mittermeier et al., 2011) and considered as a comprehensive umbrella term for the extent of nature's variety or variation within the natural system; both in number and frequency (Rawat & Agarwal, 2015). Biodiversity is defined as "the variability among living organisms from all sources, including, but not limited to, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, diversity between species, and diversity of ecosystems"(CBD, 2010). However, as a synonym for "nature" or "life on Earth," biodiversity is commonly defined as the sum total of living things and the ecological processes associated with them. Genetic diversity - the variety of genes within a species, or the variety of observable characteristics that those genes produce; species diversity - the variety of species within a community or collection of organisms; and ecological or ecosystem diversity - the overall diversity of ecological processes within and among ecosystems (CBD, 2010).

The climate is changing faster than ever before. Temperature and precipitation changes are two of the most important factors in determining overall climate change.Since the Industrial Revolution, there has been a strong local, regional, and global change in long-term average temperature, precipitation, and other weather variables (IPCC, 2014). Rising global temperatures are caused by an increase in the accumulation of carbon dioxide and other greenhouse gases in the atmosphere. Global surface temperatures have risen by approximately 1°C since the twentieth century, with another increase of 2-4 °C expected by the end of the twenty-first century (IPCC, 2013). However, temperature and precipitation changes occur at different rates around the world (Working et al., 2010). This fluctuation in climate change poses a significant threat to biological diversity.

This trend is due to the close relationship between climate change and biodiversity, as well as their mutual effects. For example, the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD) both recognize that climate change is one of the greatest threats to biodiversity and that some of the actions proposed to mitigate climate change may also pose a threat to biodiversity. There are key programs of work within the CBD that address climate change adaptation (for example, forest biodiversity and mountain biodiversity). Furthermore, the UNFCCC explicitly recognizes that adaptation is critical to mitigating the effects of climate change. For example, the Bali Action Plan, adopted at the UNFCCC COP13 in Bali in December 2007, identified adaptation as one of the key building blocks required for a strengthened future response to climate change in order to enable full, effective, and sustained implementation of the Convention (UNFCCC) through long-term cooperative action now, up to, and beyond 2012. Parties established the Cancun Adaptation Framework (CAF) in December 2010 at the Cancun Climate Change Conference with the goal of enhancing adaptation action, including through international cooperation and coherent consideration of adaptation issues under the Convention (Fao, 2007).

Despite the importance of adaptation in these conventions and the recent development of frameworks and work plans, progress in developing appropriate methodologies for integrating climate change adaptation strategies into conservation planning has been slow (Hannah, 2010; Poiani *et al*., 2011). One of the reasons for this slow progress is widespread misunderstanding about what an adaptation plan/strategy/action is in comparison to modern conservation (Andrade *et al*., 2011; Seimon *et al*., 2011). This confusion is not limited to academia—policymakers, practitioners, and donors from all over the world are frequently asking for more guidance on what adaptation is (and is not), and what adaptation strategies are most appropriate in specific locations (Andrade *et al*., 2011; Seimon *et al*., 2011). It has not helped that many conservation organizations advocate "business as usual" adaptation strategies at international conferences and policy gatherings in order to secure continued funding.

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as an adjustment in natural or human systems in response to actual or anticipated climatic stimuli or their effects, that mitigates harm and exploits beneficial opportunities, and as a process by which individuals, communities, and nations seek to cope with the effects of climate change, including variability (IPCC, 2007). Adaptation is the process by which societies become more capable of coping with an uncertain future. Adapting to climate change entails taking the appropriate steps to reduce the adverse effects of climate change by implementing the necessary adjustments and modifications (UNFCCC, 2007). It is the process of adapting to the actual or predicted climate and its consequences. Adaptation in human systems seeks to mitigate or avoid harm and exploit beneficial opportunities. In certain natural systems, human intervention may facilitate adaptation to anticipated climate and its consequences (IPCC, 2014).

As highlighted by the UN Framework Convention on Climate Change (UNFCCC), the most effective adaptation strategies in developing countries are those that address a combination of environmental stresses and factors. Strategies, policies, and programmes with the highest probability of success must link with coordinated efforts aimed at alleviating poverty, enhancing food security and water availability, combating land degradation and soil erosion, reducing loss of biological diversity and ecosystem services, as well as enhancing adaptive capacity and enhancing the food production chain within the context of sustainable development. Social inequalities, such as differences in land tenure and lack of access to resources such as credit, education, and decision-making, inhibit people's ability to adapt (FAO, 2008a).

Adaptation strategies to climate change can be categorized as either autonomous or private or planned or public sector. Private adaptation strategies consist of actions taken by non-state entities, such as farmers, communities, organizations, or businesses, in response to climate change. Public adaptation entails actions taken by local, regional, or national governments to provide infrastructure and institutions to mitigate climate change's negative effects. Public adaptation strategies include the development of new irrigation infrastructure, transport or storage infrastructure, land use arrangements and property rights, and institutions for watershed management (Stachowitsch, 2010). According to Elbehri *et al*., (2011) adaptation to climate change is a multi-dimensional, ecological and socio-economic process. Farmers adjust their planting systems in response to climate change in a manner that is largely autonomous at the regional level. Farmers engage in autonomous adaptation in response to shifting precipitation patterns by altering their crops and planting and harvesting dates. Planned adaptation, on the other hand, occurs at the sector and national levels and includes policies such as addressing changes in food insecurity, identifying vulnerabilities, reassessing agricultural research priorities, and bolstering agriculture extension and communication systems. While pursuing sector-level and long-term adjustment, planned climate change adaptation action should build upon, coordinate with, and remove impediments to autonomous local adaptation. Planned adaptation measures are deliberate policy options or response strategies, frequently multi-sectoral in nature, intended to alter the agricultural system's adaptive capacity or facilitate specific adaptations. In order to overcome some of the uncertainty surrounding the role of biodiversity in adapting to climate change, as well as the ongoing debate and discussion within the conservation community, I wished to first describe and assess the efficacy of the various strategies currently employed to integrate climate change adaptation into biodiversity conservation (with examples). As a result of conducting this review, I have identified a number of characteristics that appear to be essential for effective adaptation to climate change with respect to the conservation of biodiversity.

2.2 Maintaining and restoring native ecosystem

Utilizing biodiversity and ecosystem services as part of a comprehensive adaptation strategy to help people adjust to the negative effects of climate change (CBD, 2009) & Policies and actions based on the concept that protecting or restoring ecosystem services reduces society's susceptibility to climate change (Vignola *et al*., 2009). In reality, Biodiversity provides a vast array of ecosystem services (provisioning, regulation and maintenance, and cultural functions) that are vital to human well-being. These services, among others, play a vital role in regulating the climate, so contributing significantly to climate change adaptation. Alternatively, ecosystem-based adaptation approaches make it possible to conserve and restore (e.g. river) ecosystems while simultaneously mitigating the societal effects of climate change (e.g. flooding). They can provide both answers to climate change concerns and long-term support for ecosystem functioning, frequently bringing numerous advantages at relatively cheap cost. Ecosystem-based adaption solutions are applicable to all industries. Mangroves for coastal defense, flood plain management for flood defense, and conserving genetic variety for agriculture sector adaptation are examples of these tactics (Scarano, 2017). Existing good practices include wind-sheltering and breaks to increase the resilience of rangelands in Sudan, reforestation of mangroves to protect shorelines from storm surge and sea-level rise in the Philippines, sea-level rise land acquisition programs in the United States, and drought-adjustment of planting dates and crop varieties in Mexico and Argentina. Nonetheless, these techniques are limited and largely ad hoc, and much more must be done. Two primary strategies for adapting to and mitigating climate risks are already in place to strengthen the role of ecosystem management, and they should be utilized to their maximum potential.

Management Integrated Water Resources (IWRM) (Moka et al., 2015) to manage increasing water scarcity, and Integrated Coastal Zone Management (ICZM) (Scarano, 2017) to manage the threat of sea level rise.

According to (K. MacKinnon, C. Sobrevila, 2008) Maintaining and restoring native ecosystems, increased protection and management of natural ecosystems, and more sustainable management of natural resources and agricultural commodities must be central to adaptation efforts, according to the report. Biodiversity conservation and protected areas can play a crucial and cost-effective role in conserving biological resources and decreasing climate change susceptibility. The significant significance that better forest conservation may play in safeguarding development investments. To preserve a significant irrigation investment in North Sulawesi, Dumoga-Bone National Park was formed in Indonesia. Similarly, a new conservation area in Laos will conserve the trees surrounding the Nam Theun 2 Dam, so extending the durability of the hydroelectric producing infrastructure. Important for shelter belts and flood management, coastal protected areas in Croatia, Bangladesh, Indonesia, Honduras, and Lithuania are safeguarding coastal forests, marshes, floodplains, and mangroves. Forest services such as coastal protection and nursery grounds for high-quality fisheries are increasingly acknowledged as indispensable to the coastal economy of these nations and the way of life of the communities that depend on them. In Bulgaria, the World Bank is collaborating with WWF and other organizations to restore natural wetlands along the Danube River as filter beds to remove pollutants and offer habitat for native wildlife.

On the other hand, wetland habitats are among the most vulnerable on the planet, although they serve many essential ecological functions. Wetlands and freshwater ecosystems in the mountains serve as vital water recharge regions, an essential supply of water for downstream towns' irrigation and consumption. Wetlands along the coast serve as natural barriers that shield coastal communities from storms and other natural dangers, thereby minimizing the risk of catastrophe. For instance, inland regions covered by healthy mangroves have often suffered less from major weather disasters such as the 2004 tsunami that struck Southeast Asia and Cyclone Nargis, which struck southern Myanmar in 2008. Many of the world's poorest people rely on the high quantities of fish and other proteins produced by wetland ecosystems, freshwater rivers, and lakes. Likewise, mangroves serve as vital nurseries for fish, shrimp, and other marine invertebrates. Recent studies conducted in the Gulf of Mexico indicate that mangrove-associated fish and crab species account for 32% of the region's small-scale fisheries landings and that mangrove zones can be valued at $37,500 per hectare yearly. The degradation of mangroves has a significant economic impact on regional fishing communities and agricultural production. (K. MacKinnon, C. Sobrevila, 2008). Therefore, preserving biodiversity will aid in sustaining ecological resilience. In this context, resilience is defined as the capacity of a system to absorb disturbance and reorganize while experiencing change but retaining essentially the same function, structure, identity, and feedbacks (Braatz, 2012). The assessment of the significance of biodiversity within ecosystems and the capacity of ecosystems to withstand human-induced damages are intrinsically linked to the concept of ecosystem resilience (e.g. habitat destruction and fragmentation). Understanding the importance of biodiversity within ecosystems (such as trophic interactions, functional features, abundance, and distribution) is much more important than merely quantifying species richness. The link between biodiversity, ecological services, and human well-being has been the subject of few research to far (MEA, 2005). It is essential to recognize that within an ecosystem, the ability to merely buffer negative consequences is insufficient (ecosystem resistance). The ecosystem must be able to restructure itself after a disturbance, adapt to the new circumstances, and continue to provide essential ecosystem services. A non-resilient ecosystem will decline or even switch to less acceptable states in response to a disturbance (Holling, 2001). Ensuring the survival of species within their particular native environments by allowing their migration and dispersion across landscapes can boost ecosystem resilience. As a result, ensuring biological connection in landscapes helps mitigate the harmful effects of fragmentation and climate change. Consequently, connection protection efforts can promote the functioning of ecosystems, the delivery of ecosystem services, and the socioeconomic benefits of these services.

2.3. Agro biodiversity

Agrobiodiversity, also known as agricultural biodiversity or the genetic resources for food and agriculture, is an essential subset of biodiversity that plays a crucial role in global food security and is increasingly endangered by global climate change (FAO, 2005). Agrobiodiversity is the result of interactions between genetic resources, the environment, and the management methods and practices employed by farmers and herders. Both natural selection and human intervention have contributed to its evolution over millennia (GIZ, 2015). It includes crops, cattle, forestry, and fisheries. It includes the genetic resources (varieties, breeds) and species utilized for food, fodder, fiber, fuel, and pharmaceuticals (Johnston, 2016). The food and livelihood security of a great number of people depends on the sustainable management of numerous biological resources that are essential for food and agriculture (FAO, 2005).

Biodiversity has a crucial part in ecological activities that offer sustaining, supplying, regulating, and cultural benefits. It extends beyond the provision of material well-being and means of subsistence to include security, resilience, social relationships, health, and freedoms and options. These services are necessary for human health (MEA, 2005). Functional complementarity, which argues that the bigger the number of species, the greater the number of niches inhabited, and thus the higher the productivity of the ecosystem, is positively connected with biodiversity and ecosystem production (Wilby and Hector, 2008). In order to promote resilience to changing environmental circumstances and pressures, biodiversity in all its components increases resilience. The capacity of genetically varied people and species-rich ecosystems to adapt to climate change is stronger.FAO promotes the use of indigenous and regionally adapted plants and animals, as well as the selection and propagation of crop types and autochthonous races that are resistant to or suited to harsh conditions. The selection of crops and cultivars with tolerance to abiotic stresses (such as high temperature, drought and flooding, high salt content in soil, and resistance to pests and diseases) enables the exploitation of genetic variability in new crop varieties if national programs have the required capacity and long-term support to use them. FAO and other like-minded institutions are planning to launch the Global Initiative on Plant Breeding Capacity Build (GIPB) initiative at the governing body meeting of the International Treaty on Plant Genetic Resources for Food and Agriculture in order to strengthen the capacity of developing countries to implement plant breeding programmes and develop locally-adapted crops (FAO, 2007). Therefore, a diverse portfolio of activities based on the contributions of agricultural biodiversity (such as crop cultivation, harvesting of wild plant species, herding, fishing, and hunting) contributes to the sustenance of rural livelihoods because it increases their long-term resilience in the face of negative shock trends. In general, increased diversity fosters greater adaptability since it increases the likelihood of substituting declining opportunities with those that are expanding (FAO, 1999).

For example, according to (UNEP, 2015) It has been stated that the natural and agricultural biodiversity in Algeria is extraordinarily high, with over 16,000 recognized species. The known marine biodiversity consists of 3,183 species, 720 genera, and 658 families. It is believed that there are 713 species of maritime flora and up to 4150 if littoral and island vegetation as well as marine and littoral ornithological fauna are included. Likewise, mountain biodiversity is quite rich. These agrobiodiversity techniques must be adapted to climate change and its effects through the funding of fundamental research and development, including the promotion of drought-resistant crop varieties and enhanced pest, disease, and weed management. The introduction of trees in agriculture, such as in agroforestry and silvo pastoralist systems, is regarded as an effective adaptation strategy due to the fact that trees in or near agricultural fields provide regulating services that reduce the susceptibility of cropping systems to climate variations. During droughts, the deep exploration of soil by tree roots for water and nutrients benefits crops. By enhancing soil organic matter, porosity, infiltration, and soil cover, trees enhance soil fertility and protect them from erosion (Verchot *et al*., 2007). As research in Malawi and Zambia demonstrates, nitrogenfixing plants boost soil nutrients and water infiltration, hence enhancing the drought resistance of crops (Garrity *et al*., 2010). In Niger, areas with tree regeneration were less affected by recent droughts in terms of wheat production (Sendzimir *et al*., 2011). As shade trees regulate temperature and humidity and provide protection from wind and storms, they can also enhance the resilience of coffee and cacao production in Mexico, for instance (Lin, 2010). Similarly, numerous studies on agroforestry systems have emphasized trade-offs. High tree cover, for instance, provides soil protection but limits the light available to crops in the understory, necessitating the finding of the contextspecific tree cover that maximizes the benefits of agroforestry. Other tradeoffs exist between average yields and resilience: tree cover protects crops from climate stress, but reduces average yields in the absence of stress. Depending on climate scenarios and production methods, tree ecosystem services may contribute differently to crop adaptation to climate change in agroforestry. (Verchot *et al*., 2007).

Although the study on the function of agrobiodiversity in adapting to climate change in Ethiopia and South Africa revealed that the most prevalent adaptation mechanisms include: Utilization of various crops or crop kinds, Tree Planting, Soil Conservation, Altering Planting Dates, and Irrigation (Bryan et al., 2009). The adoption of diverse crop varieties, tree planting, soil conservation, early and late planting, and irrigation were highlighted in an Ethiopian Nile Basin study on the factors influencing farmers' choice of adaption strategies to climate change (Deressa *et al*., 2009). Traditional and modern coping mechanisms in Ethiopia for climate variability and extremes include changes in cropping and planting practices, reduction of consumption, collection of wild foods, use of inter-household transfers and loans, increased petty commodity production, temporary and permanent migration in search of employment, grain storage, sale of assets such as livestock and agricultural tools, mortgages on land, and credit from merchants and money lenders (NMA, 2007). Also, according to Easterling *et al*., (2007) Adaptation options in agriculture include the use of different varieties or species, new cropping practices such as timing of planting, greater use of water conservation and management technologies, diversification of on-farm activities, enhancement of agro-biodiversity, adapted livestock and pasture management, and improved management of pests, diseases, and weeds.

2.4. Landscape Connectivity

To enable plant and animal species to adapt to climate change, maintaining connectivity between natural habitats and along altitudinal gradients will be essential. Corridors of natural habitats inside modified production landscapes and connections between protected areas allow species to migrate and maintain viable populations. The Maloti-Drakensberg Trans-frontier Corridor in Lesotho and South Africa, the Vilicabamba-Amboró Corridor in Venezuela, Colombia, Ecuador, Peru, Bolivia, and northern Argentina, and a network of corridors in Bhutan are all receiving assistance from the World Bank. A multi-donor partnership, the Critical Ecosystem Partnership Fund (CEPF) is providing strategic assistance to engage nongovernmental organizations, indigenous and community groups, and other civil society partners, including the private sector, in biodiversity conservation within 18 of the world's biodiversity hotspots. In a number of these essential ecosystems, CEPF funding focuses on actions that strengthen the conservation and management of vital biodiversity areas, such as protected areas and biological corridors (K. MacKinnon, C. Sobrevila, 2008). In contrast, riparian forests are the most biodiverse ecosystems, serving to moderate stream temperatures and improve landscape connectivity for the migration of species (Chazdon et al., 2009). Enhancing habitat connectivity, increasing redundancy and buffers, minimizing landscape synchronization (by preserving a variety of successional phases), realigning disrupted conditions, anticipating surprises, and locating and safeguarding refugia are examples of these activities (Millar *et al*., 2007). Utilizing best management techniques and riparian management zones helps prevent harm to riparian regions caused by management activities. Under this strategy, an example of an adaptation mechanism would be promoting conifer plants to maintain cooler stream temperatures and stream shadowing. The replanting of riparian regions in agricultural areas to minimize erosion into surrounding water bodies is another landscape-level example.

2.5. Role of protected area to adapt climate change

Globally and locally, protected areas play a critical role in assisting with climate change adaptation.

However, their significance in addressing climate change is currently undervalued in the formation of national strategies and policies in various nations. To determine the significance of protected areas in managing the spread of invasive alien species associated to land degradation and posing a threat to food security and water supply, it is necessary to conduct research. The protection of agrobiodiversity is necessary to supply specialized gene pools for the adaptation of crops and livestock to climate change. The administration of maritime protected areas permits the maintenance of fisheries. Therefore, protected areas preserve vital ecological services that can boost climate change resistance, resilience, and lessen the vulnerability of human livelihoods. Frequently, protected places are the source of both clean water and greater water flow. 33 of the world's greatest cities, for instance, obtain their drinking water from catchments in protected forest regions. Protected areas provide sustainable food sources for populations. Protected places conserve and assist regenerate marine and freshwater fish populations. Diverse research demonstrated that fish numbers and sizes are growing in marine protected zones. (Côté *et al*., 2001; Roberts *et al*., 2001).

Protected areas protect crop relatives in the wild in order to promote crop breeding and pollination services. In addition to preventing the spread of vector-borne diseases, protected areas with healthy ecosystems allow access to traditional treatments. Protected areas can also contribute to mitigating the causes and impacts of climate change by including mitigation and adaptation techniques into their management. Protected places can reduce the loss of carbon from plant and soil that is already there. In 39 national parks of Canada, for instance, 4,432 million metric tons of carbon are stored; in

Madagascar, new protected areas covering 6 million hectares account for 4 million metric tons of prevented CO2 each year. Globally, around 15% of the world's terrestrial carbon is stored in protected areas (Table 1). Protected areas can be an effective land management approach for preventing land conversion and carbon loss..

Table 1. Adopted from global carbon storage in protected areas per region (Dudley *et al*., 2010)

Numb.	Region	Carbon Stock (Gt)		Percentage
		Total	In protected area	In protected area
1	North America	388	59	15.1
2	Greenland	5	2	51.2
3	Central America and Caribbean	16	4	25.2
4	South America	341	91	26.8
5	Europe	100	14	13.6
6	North Europe	404	36	8.8
7	Africa	356	49	13.7
8	Middle East	44	3	7.8
9	South Asia	54	4	7.2
10	East Asia	124	20	16.3
11	Southeast Asia	132	20	15.0
12	Australia and New Zealand	85	10	12.0
13	Pacific	3	0	4.3
14	Antartic and Peripheral Island	1	0	0.3

Note: that figures for carbon stocks have been rounded up but percentage figures were calculated from the actual numbers

Urban protected areas, on the other hand, contribute to the adaptation of cities to climate change. In fact, dunes cordon maintenance and restoration constitute natural coastal barriers. Wetlands and estuaries along the coast are effective storm surge buffers and species refuges. Kelp beds are also dissipators of wave energy. Rehabilitating a river enables the prevention of flooding. The maintenance of water flow and water quality is aided by the sustainable management of upland wetlands, forests, and floodplains. Protected areas permit the management of invasive alien species linked to land degradation and posing a threat to food security and water supplies. The conservation of agrobiodiversity is necessary to provide specific gene pools for the adaptation of crops and livestock to climate change. The administration of marine protected areas permits the maintenance of fisheries. (Tual, 2014).

3. The way forward

Biodiversity is the variety of all life, from genes to species, that make up the intricate interactions between life and habitats that constitute ecosystems. As the foundation for the natural processes that regulate climate, biodiversity is inextricably linked to the earth's climate and to climate change as a result. Thus, the relationship between biodiversity and climate change is close. Similarly, biodiversity conservation and climate change adaptation are strongly interdependent and interdependent. Managing and protecting biodiversity will help humans adapt to climate change by mitigating its negative effects. Consequently, biodiversity will be more resistant to climate change and better able to adapt if we maintain healthy ecosystems. This will also be crucial for human adaptation to climate change, as our prosperity and well-being depend on the services provided by healthy ecosystems. For effective adaptive management of natural systems under conditions of climate change, the following approaches and actions must be taken into account:

- Recognize that natural processes are dynamic, and that species are expected to respond uniquely to the effects of climate change. Therefore, habitat management must be adaptable, flexible, and specific.
- Respond to shifting conservation priorities (due to climate change) and learn from local, regional, national, and international experiences by adapting conservation targets in the various conventions, conservation mechanisms, and conservation plans.
- Integrate the principles of adaptive management of natural habitats into other management plans and land use strategies in order to enable or support the natural development of climate-resilient ecosystems and to promote the services they can offer in the context of climate change adaptation.

4. References

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