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The Role of Biodiversity and Ecosystem Services in Carbon Sequestration and its Implication for Climate Change Mitigation

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Abstract

Understanding the role of biodiversity in carbon sequestration as a function of ecosystem under changing climate is crucial to manage the future biodiversity and ecosystem resources in order to adapt and mitigate to climate change. This review paper presents an overview the role of biodiversity and ecosystem service in carbon sequestration as an approach to mitigate climate change by reducing the greenhouse gas from the atmosphere in order to cope with challenges and threats to the current services provision.In worldwide global warming is one of the most discussed topics due to natural and human induced increments in atmospheric concentrations of greenhouse gases. Rapidly increasing populations and excessive utilization of natural resources will have impacts on biodiversity and ecosystems services. Climate change impact on human wellbeing is measured by the ecosystem services change caused by climate-related biodiversity change. Since, terrestrial ecosystems take up carbon from the atmospheric carbon dioxide pool during photosynthesis, and return the majority of it back by combustion or the respiration of animals, plants and microorganisms. So, identifying the role of biodiversity in carbon sequestration as a function of ecosystem services is crucial to reduce the future impacts of climate change (climate change mitigation) through carbon sequestration process. Biodiversity and natural ecosystems provide society with important goods and services. Numerous scholars found that biodiversity plays an important role in climate regulation, carbon sequestration, nutrient cycling, provision of food, provision of clean air and water, water cycling, crop pollination, and disease regulation and also has an economic value. Ecosystem based adaptation and mitigation (carbon sequestration), through the protection of healthy ecosystems, make use of the multiple services such natural capital provides, to help stabilize the climate system and support societal adaptation sustainably. This review paper starts with highlighting the studies on the linkage between biodiversity and ecosystem service, attributes of biodiversity, ecosystem service, ecosystem service trade-offs and synergies, ecosystem services in regulating greenhouse gas emissions, and implications of biodiversity and ecosystem service provision in carbon sequestration. Finally, the paper concludes that management of biodiversity and natural ecosystem has great role in reducing the greenhouse gas from the atmosphere to mitigate climate change.

Keywords: Biodiversity; Carbon Sequestration; Ecosystem service; GHGs; Climate Change Mitigation

Introduction

Ecosystem and biodiversity services are declining worldwide, policy makers and spurring scientists to act together to identify effective policy solutions [1]. Numerous scholars report that human population size where rapidly increasing currently. Because of these changing patterns of consumption and growth, humans are altering ecosystems on a global scale. Recent research has confirmed that both ecosystem services provision and biodiversity declines with land use intensification, there is still much debate among the scientific community about the different strategies that may be essential to protect both biodiversity and services [2]. Change in biodiversity affects the flow of ecosystem service the benefits that people get from ecosystems. Climate change is amongst the most important determinants of change in the distribution and abundance of species in both managed ecosystems such as agriculture, production forests, cities and many coastal zones, and natural terrestrial and marine ecosystems [3]. Climate change is also an effect of land uses that generate greenhouse gases (CO_2, CH_4, and N_2O) and of alteration in biological stocks of carbon in terrestrial and marine system (green and blue carbon).

Strengthening the science-policy interface for biodiversity and ecosystem services will contribute to the conservation and sustainable use of biodiversity, to long-term human well-being, and to sustainable development (www.ipbes.net). Knowledge of the effects of biodiversity change on ecosystem functioning has progressed rapidly in the past 20 years. Recent syntheses have shown that a large body of evidence. is now available, describing how biodiversity loss affects the functioning of ecosystems and that this impact is, at least in the case of primary productivity, as large as some other global change drivers, including climate warming, elevated carbon dioxide, ocean acidification, or nutrient additions [4-5]. Despite these impacts, current knowledge of the links between measures of biodiversity (species richness, functional diversity) and ecosystem services that directly affect human well-being is still patchy [6]. Plants and soil are natural regulators of atmospheric CO_2 [7]. Whereas plants sequester atmospheric carbon, soils deposit it for decades. Win–win solutions for carbon dioxide control and biodiversity are possible, but careful evaluation and planning are needed to avoid practices that reduce biodiversity with little net decrease in atmospheric carbon dioxide [8].

Carbon flows naturally in the earth system through the atmosphere, biosphere and lithosphere in an ensemble of processes known as the carbon cycle [9]. However, emissions of carbon in the form of carbon dioxide, one of the major green-house gases, have increased over time both due to the use of fossil fuels for energy and due to historic anthropogenic land use and land cover changes. These processes have largely increased its atmospheric concentration, contributing to climate change and increasing the likelihood of environmental and economic losses in the future. The capacity of ecosystems to influence the regulation of the concentration of greenhouse gases in the atmosphere, and therefore climate is an essential ecosystem service with many benefits for human societies [10], from the mitigation of socioeconomic damages associated with climate change [11] to the maintenance or improvement of local economies [12,13].

Terrestrial ecosystems, including forest, semi-natural and agricultural ecosystems, play an important role in carbon cycling. They act both as carbon sinks, through carbon sequestration and storage in plant biomass, litter and soil organic matter, and as carbon sources, through emission of carbon from biological processes such as respiration. This review paper highlights the role of biodiversity and ecosystem services linkages in carbon sequestration as an approach to mitigate climate change.

Link between Biodiversity and Ecosystem Services

The link between biodiversity and ecosystem services is not well understood, and different studies have found varying levels of ecosystem services in relation to biodiversity in different habitats [14]. The Millennium Ecosystem Assessment (MEA, 2005) identifies biodiversity and the many associated ecosystem services as a major factor determining human wellbeing. The well-being of humanity depends to a large extent on the benefits derived from the processes and functions that take place within ecosystems. Such processes and functions are called ecosystem services. Biodiversity plays an important role in the delivery of many of these benefits. The relationship between biodiversity, ecosystem functioning and ecosystem services is still poorly understood [15,16]. Recently numerous scholars have been reported about biodiversity and ecosystem services [17-20]. Over the last few decades, numerous studies and experiments have investigated whether more species in a community would help maintain the provision of ecosystem services, or specifically if there is a positive relationship between biodiversity and ecosystem functioning [21].

Most studies have focused on aboveground terrestrial and aquatic ecosystems and have shown, in general, a consensus for the relationship between biodiversity and ecosystem function, stability and resource use efficiency. Although it is still being resolved, evidence shows that increased species richness on average leads to greater functioning: for example, productivity in plant communities increases nutrient retention in ecosystems, and provides greater stability in terrestrial and aquatic ecosystems [22-24]. Human well-being is a multifaceted concept which includes the presence of positive emotions and moods [e.g., contentment, happiness], the absence of negative emotions (e.g., depression, anxiety), satisfaction with life, fulfillment, resilience and positive functioning (Centers for Disease Control and Prevention, no date).

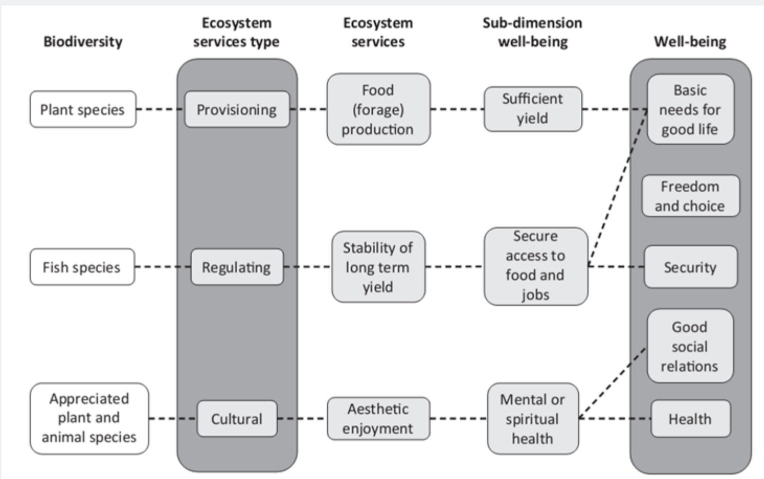

Figure 1: Biodiversity is linked to ecosystem services and the different components of wellbeing. Selected examples are used to illustrate these linkages [55,56].

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Wellbeing components depend differentially on financial, social, infrastructure and natural capital [25]. Adequate nourishment, access to clean drinking water, or access to traditional medicine are examples of needs that depend largely on ecosystem services. Plant species richness can contribute to higher forage production, sufficient meat production, and meeting basic food security needs (Figure 1). Fish population diversity can contribute to yield stability and thus food and job security [26]. Appreciated plants and animals can contribute to aesthetic enjoyment, spiritual and mental health and thus to overall health and good social relations. Yet the relative contribution of biodiversity itself to these different components of wellbeing is much harder to assess [27] (Figure 1).

Uncertainty about the links between biodiversity and ecosystem services remains considerable [28]. These uncertainties arise from: i) mismatches between ecosystem functions measured and final ecosystem services; ii) mismatches between study conditions and management conditions; iii) insufficient consideration of all functions upon which a service depends; iv) insufficient integration of multiple potentially critical components of biodiversity; v) confounding environmental factors; vi) trade-offs between the positive and negative effects of changes in biodiversity on various ecosystem functions that underlie ecosystem services; vii) context-dependent patterns; and viii) different scales between studies linking biodiversity and both the management and delivery of services [29].

Therefore, integrated interdisciplinary research is needed to understand the consequences of different types of management for the key components of biodiversity that underpin different bundles of ecosystem services and for the benefits derived by stakeholders [30]. More research is need to understand how and when the links between biodiversity and ecosystem services are dependent on the biophysical, management, and societal context. A new network of long-term, interdisciplinary, adaptive, and participatory studies can be used to fully assess the contributions of biodiversity to ecosystem services and people's well-being (Figure 2). For instance, a network of sites with contrasting social and ecological conditions and a common experimental design could be used to monitor biodiversity, different bundles of services and the flow of benefits to societies. Designing and monitoring management experiments with stakeholders would ensure that the experiments/monitored variables were the most relevant to society.

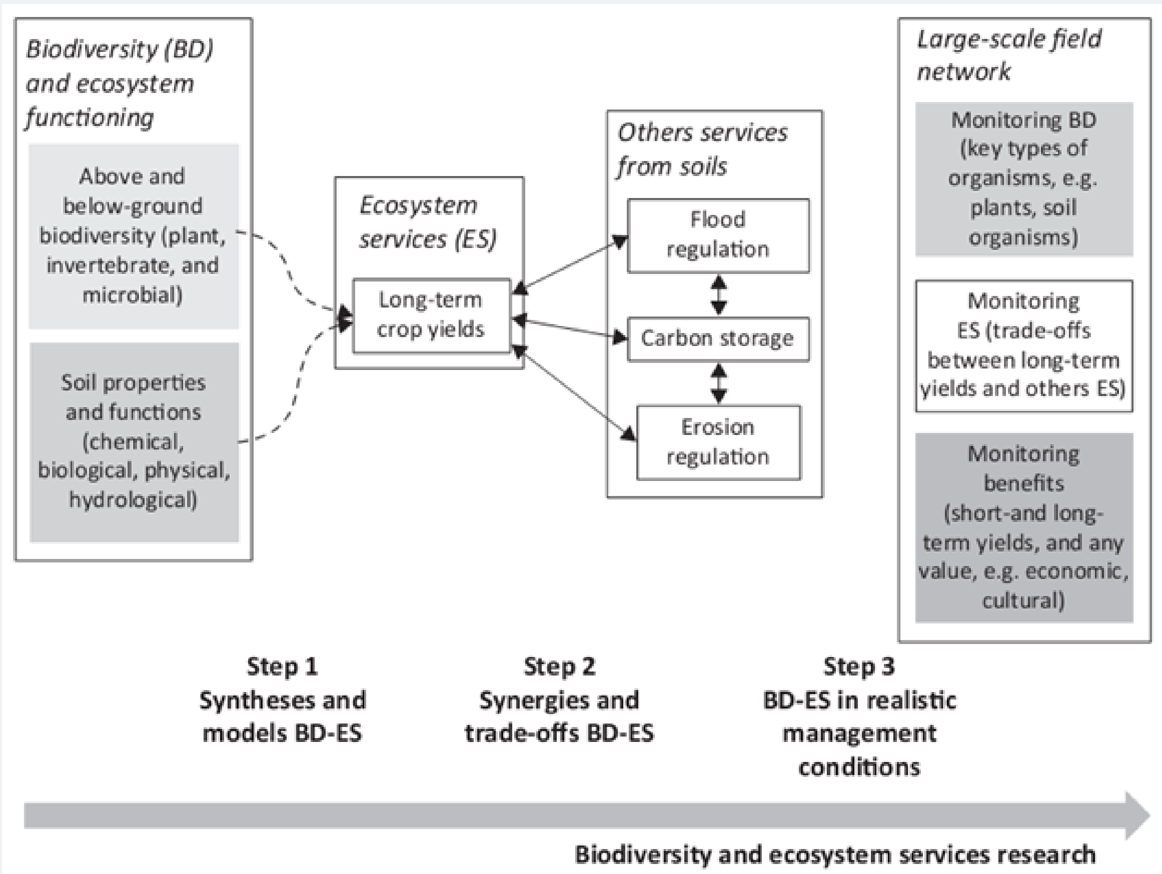

Figure 2: Steps leading to a new generation of biodiversity and ecosystem services research, using the effects of biodiversity through soil functions on long-term crop yields as an example [2]. According to numerous scholars [26,9,1] conclude that, there is sufficient evidence that biodiversity positively affects effectiveness or reliability of ecosystem services.

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Figure 2 Steps leading to a new generation of biodiversity and ecosystem services research, using the effects of biodiversity through soil functions on long-term crop yields as an example [31]. According to numerous scholars conclude that, there is sufficient evidence that biodiversity positively affects effectiveness or reliability of ecosystem services [31-33].

Biodiversity Attributes

Biodiversity broadly encompasses the number, abundances, functional variety, spatial distribution, and interactions of genotypes, species, populations, communities, and ecosystems [34]. Biodiversity attributes may have positive effects on some services but negative or no effects on others. When biodiversity characteristics are assessed for any location or region, three attributes of biodiversity are considered (http://www.biodiversitybc.org) Composition describes the parts of each biodiversity component in that area (for example, habitat types, species present, genetic diversity within species). Structure refers to the physical characteristics supporting that composition (for example, size of habitats, forest canopy structure, etc).

Function means the ecological and evolutionary processes affecting life within that structure (for example, pollination, natural disturbances, predator-prey relationships). To analyze the influence of biodiversity on ecosystem functions and service delivery in a structured manner, the concept of ecosystem service provider can be useful. An ecosystem service provider only relates to specific organisms (from vascular plants, vertebrates to microbes) and variation of their attributes (e.g., genetic diversity, species diversity, species richness, functional diversity and vertical diversity) [35,36]. It is becoming increasingly clear that even the loss of a few species from a diverse community could have an adverse impact on ecosystem functioning and services [37]. However, diversity effects tend to increase over time in long-term experiments. More importantly, the relationship between biodiversity and ecosystem functioning becomes increasingly linear over time. Thus, long-term studies tend to indicate that even the loss of a few species from diverse communities could have large impacts on ecosystem services, while results from short-term studies tend to suggest that most species are redundant. Mace conclude that, biodiversity has a key role in ecosystem delivery either to ensure the regulating ecosystem processes (e.g. Soil Fertility) or to provide a product or cultural service (e.g. Wild Food or Aesthetic Appreciation) and the short-term species composition and biomass may be more important, biodiversity has a key role in ecosystem service delivery [38]. Regulating ecosystem services are quite well studied, while production and especially cultural services are less studied [39]. In the large majority of cases a positive relationship is found between species diversity and ecosystem service provisioning.

Recently, many have emphasized the importance of biodiversity for ecosystem services, for example "biodiversity enhances the ability of ecosystems to maintain multiple functions" [40],"species richness has positive impacts on ecosystem services" [41], "biodiversity decreases the occurrence of diseases through predictable changes in host community competence" [42], "increased biodiversity enhances ecosystems services such as pollination and provide an opportunity to increase agricultural yields whilst also benefitting wildlife" [43]. It has been emphasized that many ecosystem services ultimately depend on the variety of life forms that comprise an ecosystem and that control the ecological processes that underlie all services. Therefore, a solid understanding of the linkages between biodiversity, ecosystem functioning and the production of ecosystem services is vital [44].

Ecosystem Services

Ecosystem services approaches to biodiversity conservation are currently high on the ecological research and policy agendas [45]. Ecosystem services refer to the provisions or services that are produced (directly or indirectly) by an ecosystem [46]. Humans depend to a large degree on goods provided by natural and managed ecosystems [47]. These goods and other benefits provided by ecosystems to mankind are collectively referred to as ecosystem services. Anthropogenic activities impact the diversity of organisms found in ecosystems aboveground and belowground, and thus influence the provision of ecosystem services. Consequently, there has been increasing scientific interest in the link between biodiversity and the provision of ecosystem services. The term 'ecosystem services' was defined in the Millennium Ecosystem Assessment (MEA, 2005) as 'the benefits people obtain from ecosystems', both natural and managed [48]. These services may be categorized as provisional, regulative, cultural or supporting services, also referred to as supporting processes (Table 1). The first three categories have a direct impact on human well-being, whereas the latter has an indirect impact by supporting provisional, regulative, and cultural services.

Table 1: Classification of ecosystem services [57].

Service type	Examples of goods or services provided
Provisional	Fiber; Food; Freshwater; Fuel wood and other essential resources
Regulative	Climate regulation; Disease control and suppression of pathogens; Water purification and regulation
Supporting (processes)	Nutrient cycling; Primary production; Soil formation
Cultural	Aesthetics; Cultural heritage and sense of place; Educational; Recreational; Spiritual and religious

Ecosystem Service Trade-offs and Synergies

Ecosystems have a critical role in regulating climate, and soil, water and air quality, but management to change an ecosystem process in support of one regulating ecosystem service can either provide co-benefits to other services or can result in trade-offs [49]. Ecosystem services studies have often found trade-offs between ecosystem services as well as bundles, i.e., sets of different services that interact synergistically and occur simultaneously across landscapes provided by different land uses.

Changes in biodiversity will likely lead to trade-offs in ecosystem service provision. For example, converting diverse grassland to cropland tends to provide high levels of crop production but low levels of many other ecosystem services. There is now considerable evidence that different ecosystem processes depend on different sets of plant species [50]. Ecosystem services possess both trade-offs and synergies. According to numerous scholars [51-55], ecosystem service trade-offs arise when the provision of one service is enhanced at the cost of reducing the provision of another service, and ecosystem service synergies arise when multiple services are enhanced simultaneously. With rapidly increasing populations and excessive utilization of natural resources, humans have been enhancing the production of some services at the expense of others [56]. Although the need for certain trade-offs between conservation and development is urgent, having only a small number of efficient methods to assess such trade-offs has impeded progress. Ecosystem services have the strongest synergy in .improving carbon sequestration and water interception and trade-offs in decreasing in regional agricultural production and other services [57]. Much work has been done to explore trade-offs and synergies in order to reveal the interactions that really occur among multiple ecosystem services. Less work has been done to quantify these interactions. The quantification of trade-off and synergy has strong implications for ecosystem management [58]. Ascertaining the trade-offs and synergies among ecosystem services might improve the practices based on ecosystem management, and might help governments and companies to achieve their goals [59]. Trade-offs between provisioning and regulating ecosystem services at different scales have been a main cause for concern, because regulating ecosystem services are thought to underlie the sustainable production of provisioning and cultural ecosystem services and are important for the resilience of social-ecological systems [60].

Several researches [61-63] shown that better understanding of the underlying mechanisms and motivations for trade-offs and synergies can be beneficial for planning and managing ecosystem services, because it can help to:

- **a.** Reduce undesirable trade-offs and related conflicts,
- **b.** Enhance desirable synergies (by management strategies which are able to simultaneously deliver several desired ecosystem services),
- **c.** Predict where and when trade-offs might take place in order to increase the co-benefits,
- **d.** promote honest dialogue, creativity, and learning between concerned stakeholder groups,
- **e.** lead to more effective, efficient and credible management decisions, and
- **f.** Obtain more equitable and fair outcomes by taking into account distributive impacts of ecosystem services trade-offs.

Ecosystem Services in Regulating Greenhouse Gas Emissions (GHGs)

Current and predicted pattern of global climate change are a major concern in many areas of socio-economic activities, such as agriculture, forestry, etc., and is a major threat for biodiversity and ecosystem function [64]. Climate change is a result from emission of greenhouse gases (e.g. CO_2, CH_4, & N_2O, etc.) in the past century that will cause atmospheric warming (IPCC, 2007). Ecosystems regulate the global climate by storing greenhouse gases. Carbon sequestration decreases the concentration of greenhouse gasses like CO_2 in the air. CO_2 is taken up from the air by plants during photo synthesis [65]. It is released again during decay of dead plants and animals and is taken up by soil complexes. It is delivered in and by natural vegetation like forests and peat land, but also by grasslands and crops. Terrestrial ecosystems take up carbon from the atmospheric carbon dioxide (CO_2) pool during photosynthesis, and return the majority of it back by combustion or the respiration of plants, animals and microorganisms [66]. For instance, as trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues [67]. Carbon storage is an important ecosystem function of soils that has gained increasing attention in recent years. Changes in soil carbon impacts on and feedbacks to, the Earth's climate system through emissions of CO_2 and CH_4 as well as storage of carbon removed from the atmosphere during photosynthesis (climate regulation) [68]. Ecosystems influence climate through the exchange of greenhouse gases and by reflecting radiation and converting energy to different forms [69]. Energy is entering ecosystems when atmospheric carbon dioxide (CO_2) is reduced to form organic carbon compounds during photosynthesis, a process driven by solar energy. Both energy and organic carbon are closely linked as they move through ecosystems. Thus, energy is lost from ecosystems when organic carbon is oxidized to CO_2, and returned back to the atmospheric pool by combustion or the respiration of plants, animals and microorganisms [70]. Ecosystems regulate global and regional climate (i) by providing sources or sinks of glasshouse gases (affecting global warming) and sources of aerosols (affecting temperature and cloud formation); (ii) by enhancing evapotranspiration and thereby cloud formation and rainfall [71]; and (iii) by affecting surface albedo and thereby radiative forcing and temperature [72]. Ecosystems can also affect the microclimate locally, through the provision of shade and shelter and the regulation of humidity and temperature. Amongst the ecosystem services supported by biodiversity is climate regulation. One effect of the conversion of forests to agricultural production, for example, is an increase in carbon emissions from land clearance and a decrease in sequestered carbon. At the same time, our ability to adapt to climate change depends on the diversity of species within functional groups [73]. Vegetation and well-managed soils can remove carbon from the atmosphere and ecosystem management can regulate CO_2 emissions to the atmosphere [74]. Management of ecosystems (drainage/

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rewetting of wetlands, livestock and fertilizer management) can influence N_2O and CH_4 emissions [75] e.g. ammonia (NH_3) emissions from livestock and fertilizer use can lead to increased fluxes of glass house gases (N_2O and CH_4) after deposition to terrestrial ecosystems [76]. Historically, land-use conversion and soil cultivation have been an important source of greenhouse gases (GHGs) to the atmosphere. It is estimated that they are responsible for about one-third of GHG emissions. However, improved agricultural practices can help mitigate climate change by reducing emissions from agriculture and other sources and by storing carbon in plant biomass and soils.

Climate regulation is a crucial ecosystem service and is increasingly valued by governments concerned with the global climate challenge. Forests are a large store of carbon and also act as an active carbon 'sink', removing carbon dioxide (CO_2), a greenhouse gas, from the atmosphere and storing it as carbon in living biomass, leaf litter and forest soil. This sequestration of CO_2 is an essential ecosystem service. Greenhouse gas removal is a regulating ecosystem service that contributes to reducing the scale and future impacts of climate change (climate change mitigation).

Implications of Biodiversity and Ecosystem Service Provision in Carbon Sequestration

Atmospheric carbon dioxide is increasing as a result of fossil-fuel combustion and the destruction of terrestrial vegetation. Because carbon cycles readily among the biosphere, the atmosphere, and the oceans, it should be possible to influence the store of carbon in the atmosphere by managing the store of carbon in the biosphere [77]. Carbon sequestration refers to the binding of carbon either aboveground (in the vegetation) or belowground (in soil complexes). Most literature sources find a positive relation between biodiversity attributes and effectiveness of carbon sequestration. The sequestration and storage of carbon is one of the many ecosystem services supported by biodiversity. Carbon is initially sequestered through photosynthesis before being transferred to one of a number of terrestrial pools including above-ground biomass, dead wood, litter, roots (below-ground biomass) and soil. Soil organic matter itself also confers multiple benefits for human society, e.g. enhancing water purification and water holding capacity, protecting against erosion risk, and enhancing food and fibre provision through improved soil fertility. Soil is an important carbon reservoir that contains more carbon (at least 1500–2400Pg carbon) than the atmosphere (590Pg carbon) and terrestrial vegetation (350-550Pg carbon) combined and an increase in soil carbon storage can reduce atmospheric CO_2 concentrations. Carbon storage in soils occurs in both organic and inorganic form.

Global change brought by increasing population needs and altered climatic patterns is expected to affect biodiversity, ecosystems, and ecosystem services, with significant impacts on social and economic well-being. There is widespread recognition that climate change and biodiversity are linked. Most obviously, by changing the environmental conditions within which species exist, climate change induces an adaptive response on the part of species. Ecosystem services are ultimately supplied by the interactions between societies and ecosystems through social-ecological systems. In any given ecosystem, changes in the frequency and intensity of disturbances determine the rate at which plant and animal assemblages will change. In the absence of effective management, the effects of declining biodiversity and ecosystem degradation will be exacerbated by climate change, with consequences especially for the well-being of future generations.

The relation between biodiversity and carbon sequestration is relatively well studied, where the relation between above ground biodiversity and above ground sequestration is quite consistently positive. The terrestrial ecosystems that can take up CO_2 and other carbon containing compounds are animals, microorganisms, plants, soil, and water. Terrestrial plants contain about 650 Pg carbon (1Pg = 10^{15}g) and soils 2,300Pg carbon (Table 2). Soil microorganisms are estimated to contain 110Pg carbons. Forests hold 70–90 % of terrestrial above and below ground biomass. However, the knowledge on the amount of terrestrial biomass and, thus, biomass C stock is based almost entirely on ground measurements over an extremely small and possibly biased sample pool, with many regions still unmeasured. For instance, plant roots may contain up to 280Pg carbons which is significantly higher than the previous estimate of 160Pg carbons (Robinson, 2007).

Table 2: Estimates for terrestrial ecosystem carbon storage (Pg carbon).

Storage component		Pg (Carbon)	References
Plants	Total	650	Field and Raupach [22]
	Forests	360	Pan et al. [61]
Plant roots	Total	280	Robinson [66]
	Forests	200	Robinson [66]
Soil microorganisms	Total	110	Jansson et al. [36]
Soil organic carbon	1-m soil depth	1,600	Jobbágy and Jackson [38]
	3-m soil depth	2,300	Jobbágy and Jackson [38]
Soil inorganic carbon	1-m soil depth	1700	Eswaran et al. [21]
Permafrost	Total	1,700	Tarnocai et al. [71]
Peat lands	Total	600	Yu [77]

Even less certain is the carbon storage in nonliving components. For example, about 1,700 and 1,600Pg carbon may be stored in soil to 1-m depth as soil inorganic carbon (SIC) and

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soil organic carbon (SOC), respectively. Furthermore, permafrost and peat lands may contain an additional 2,300Pg carbon. Carbon sinks in the oceans and the terrestrial biosphere provide an extremely important ecosystem services. The effectiveness of above ground sequestration increases with species diversity. Studies found that longevity of species increases the reliability of carbon sequestration in time as short-lived trees release carbon again when they die.

Therefore, terrestrial ecosystems play an important role in regulating climate, particularly in carbon sequestration. Different ecosystem types store different amounts of carbon depending on their species composition, soil types, climate and other features. Loss of or damage to ecosystems reduces their capacity to capture and store carbon. Therefore, maintaining of existing natural carbon reservoirs worldwide is essential if carbon capture and storage is to make a major contribution to climate mitigation.

Summary

This review paper builds on current state of the art that link biodiversity and ecosystem service provision particularly in carbon sequestration aspect. According recent study reports shows well managed and protected biodiversity can deliver vital ecosystem services, such as erosion control and reduced flooding; water purification and retention, they support food and health security by maintaining crop diversity and species, particularly play an important role in climate change adaptation and contribute to mitigation through the storage and sequestration of carbon. Understanding just how biodiversity is linked to ecosystem services is critical for future designing more sustainable environmental policies and developmental planning. Ecosystems have a critical role in regulating soil, and climate, air quality and water. The well-being of human society depends to a large extent on the benefits derived from the ecosystems functioning that is called ecosystem services. Biodiversity plays very important role in the provision of ecosystem services. They deliver a various range of services, from clean water to the air we breathe, that are vital to our well-being. Moreover, ecosystems can also support us face changing conditions in the future. As the impacts of climate change are now being stroked across the globe, robust and flexible methods of both adaption and mitigation are increasingly needed.

Since, current knowledge has been poorly integrated and few studies incorporate a wide range of both biodiversity attributes and ecosystem services. So, understanding on the links between biodiversity and the ecosystem services provision in carbon sequestration is the key for promoting arguments for sustainable ecological and environmental restoration.

Based on this review paper, we draw the following conclusions:

a) Understanding of the ecosystem services trade-offs and synergies can be beneficial for future planning and managing ecosystem services.

b) Increased understanding of the role of biodiversity on sustaining ecosystem services is likely to increase the relative value of services.

c) Decreasing biodiversity due climate change can alter ecosystem functioning in directions that would likely reduce ecosystem services.

d) Increasing biodiversity may result in increased ecosystem service provision.

e) Biodiversity and its ecosystem service has great role in carbon sequestration and reducing the greenhouse gas from the atmosphere in order to mitigate climate change.

f) Ecosystem based adaptation and mitigation to climate change could ensure future human well-being.

g) Therefore, strengthening the science and policy interface for biodiversity and ecosystem services will contribute to the management and sustainable use of biodiversity and ecosystem, to sustainable development, and has great role in carbon sequestration and reducing the greenhouse gas from the atmosphere in order to mitigate climate change.

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