# Controversial on biodiversity and carbon sequestration: implication for biodiversity conservation

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**Abstract**. The relationship between the level of biological diversity and the tons of carbon dioxide sequestered is an argumentative concept. Carbon sequestration happens during primary productivity which varies with the species richness. Conservationists and biodiversity institutes reveal that biodiversity has a significant positive correlation with carbon dioxide sequestered. Conversely, some scholars such as production foresters argue that the fast-growing monocrops (single-species) sink more tons of carbon dioxide than that of biologically diverse communities. This ambiguity could contribute to biodiversity loss by encouraging selected species (reduces species diversity). Despite this, no review paper on this argument has been published so far. Thus, this paper was initiated to figure out the information on controversial on biodiversity and carbon sequestration. This paper is expected to contribute to sustainable biodiversity conservation in different ecosystems by figuring out their carbon sequestration potentials.

**Key Words**: biodiversity, carbon, conservation, ecosystems, sequestration.

**Introduction**. Biodiversity is the variability among living organisms from all ecosystems and the ecological complexes (Millennium Ecosystem Assessment 2005). It could be diversity within species, between species, and of ecosystems. Ecosystems interact in complex processes and functions to produce environmental goods and services (Millennium Ecosystem Assessment 2005; Pedro et al 2016). Ecosystem services are provisioning, regulating, cultural, and supporting services. Carbon sequestration is one of the regulating ecosystem services by which atmospheric carbon dioxide is absorbed and stored in the ecosystems (Millennium Ecosystem Assessment 2005; Hicks et al 2014; Pedro et al 2016). It depends on the species and Physico-chemical properties of the ecosystems (Nelson et al 2013; Epple et al 2016).

The carbon sequestration potentials of different ecosystems have been degrading due to the anthropogenic activities and climate change impacts (IPCC 2007; Nelson et al 2013; IPCC 2014). At a global level, about two-thirds of ecosystems are degraded and one-quarter of the world's land is cultivated (Millennium Ecosystem Assessment 2005; European Commission 2009). As a result, 12% of birds, 25% of mammals, and 32% of amphibians are threatened with extinction, 20% of the world's coral reefs have been destroyed and more than one-third of global mangrove forest was lost (IPCC 2014; Pedro et al 2016). Besides, a further 10-20% of grassland and forests are expected to be converted to agriculture between 2000 and 2050 (IPCC 2014). The breakdown of organic matter by microorganisms also releases greenhouse gases like methane, carbon dioxide, and other gases to the atmosphere, even though it is naturally balanced (Perrings 2010).

Different research groups and different approaches have found different results on the relationship between biodiversity and carbon sequestration. Positive correlations were observed between species composition and aboveground biomass, tree growth, basal area, and ecosystem functioning or carbon storage in the tropical forest (Díaz et al 2009; Talbot 2010; Hicks et al 2014). At the macro-level, there is considerable variation from one tropical forest region to another in the number of species supported per unit area (Thompson et al 2012; Hooper et al 2012; Laliberté et al 2013). Nevertheless, there is no compelling evidence that the most diverse tropical forests are also the most carbon-rich (Srivastava 2005; Bunker et al 2005; Healy et al 2008; Potvin & Gotelli 2008).

The authors of this paper identified only 33 published documents pertinent to this review due to the absence of related articles published online. This indicates that less attention has been given to figure out the relationship between biodiversity and carbon sequestration. Moreover, a review paper figuring out the controversy on biodiversity and carbon sequestration and its implication for biodiversity conservation has been published so far. So, this review is new and expected to contribute to sustainable biodiversity conservation in different ecosystems by figuring out their carbon sequestration potentials.

**Carbon sequestration potentials of different ecosystems**. Many studies show that the total carbon stored in marine ecosystems correlates with species richness or level of biodiversity, even though it varies/lacks certainty in terrestrial ecosystems. Terrestrial and oceanic ecosystems are currently absorbing about half of the anthropogenic $CO_2$ emissions. In the absence of sinks, the total $CO_2$ emissions would have increased to about 500 ppm, however, it is 387 ppm due to climate change feedbacks and other pressures (Van Bochove et al 2014). Fifty years ago, for every 1 ton of $CO_2$ emitted to the atmosphere, natural sinks removed 0.6 ton, but, now the sink efficiency is decreased by 5% (Murray et al 2011). Currently, the annual global anthropogenic $CO_2$ emission is 10Gt, of which 1.5 Gt is from land-use change mostly from deforestation. Deforestation converted 40% of forest area since 1700, and it is expected to release 87-130 billion tonnes of carbon by 2100, which is greater than the amount of carbon that would be released by 13 years of global fossil fuel combustion. Mankind has already altered half of the world's natural habitats, and a single year's habitat conversion costs society US$250 billion every year into the future (IPCC 2014).

Reducing the rates of global deforestation and forest degradation will yield substantial gains for climate change mitigation and biodiversity conservation. This could be achieved by reducing the causes for forest degradation and deforestations (Sefi et al 2017). Some of the major causes for deforestation and forest degradation are human settlement, wildlife-human conflict, and agricultural land expansion (Figure 1). Moreover, marine ecosystems are among the largest of earth's aquatic ecosystems that play significant roles in the overall health of both marine and terrestrial environments and climate change mitigation (Nye 2010). They contain about 40,000 Gt C, mostly in the form of dissolved inorganic ions, which is larger than that of 800 Gt C contained in the atmosphere and 2000 Gt C in the land biosphere (IPCC 2014). Nearly half of the global primary productivity occurs in the open ocean, dominantly very near the surface. Any effects of climate change on the primary productivity of phytoplankton in the surface layer (having 90% of the life), affects all aspects of the food web (Nye 2010).

Phytoplanktons absorb $CO_2$ from the atmosphere to the surface of the oceans for photosynthesis, which is completely comparable to terrestrial consumption of $CO_2$ by trees and plants. However, the very dynamic nature of the oceans, for example, the currents and waves make understanding where and for how long the carbon is sequestered in the ocean a very challenging problem. The overall activities of aquatic lives including phytoplankton are highly affected due to climate change exacerbated by human activities such as habitat destruction, the occurrence of invasive plant and animal species, severe warming, acidification, toxins, and massive runoff nutrients in the water (Mooney et al 2009). In many regions, the primary productivity of animals and plants that live on or in the bottom of the water body and providing different services like habitat forming, climate regulation, and food for others are severely affected by the increase in marine temperature (Pedro et al 2016; IPCC 2014).

The effect of climate change on the primary productivity of marine ecosystems will depend on how temperature, salinity, biodiversity in the ecosystem, and hydrography changes in each region (IPCC 2014). As a result, a sharply declining of the population of marine species happened just in the last twenty years, for instance, 80% of the largest vertebrates such as shark and blue whale, 65% of seagrass, and 67% of wetlands were lost due to the change in climatic and weather patterns (European Commission 2009). The analysis of eighteen marines calcifies in the United States of America showed that the response to acidic waters varied for different species, some species like the blue crab and American lobster responded favorably to acidification, but most organisms responded unfavorably with increasing acidity that resulted in a decrease in growth and increases in mortality of marine species (Nye 2010).

The highest impact of climate change on the world's oceans is on habitat-forming species such as corals, seagrass, mangroves, salt marsh grasses, and oysters where these organisms form the habitat for thousands of other species in marine ecosystems (IPCC 2014). For example, coral reef ecosystems are declining and are likely to be declined by 2050 because of anomalously warm sea temperatures combined with local impacts such as habitat destruction, food scarcity, and ocean acidification (Pedro et al 2016). Although worldwide mangrove deforestation is occurring at a rate of 1 to 2% per year, the risk to mangroves from rising sea levels are increasing, and only 10-20% of mangrove forests will remain by 2100 (IPCC 2014). Studies show that over 100 million people in six southeast Asian countries, known as the "Coral Triangle" would face the problem of food security due to sea-level rise, loss of coral reefs, and calcification (Mooney et al 2009).

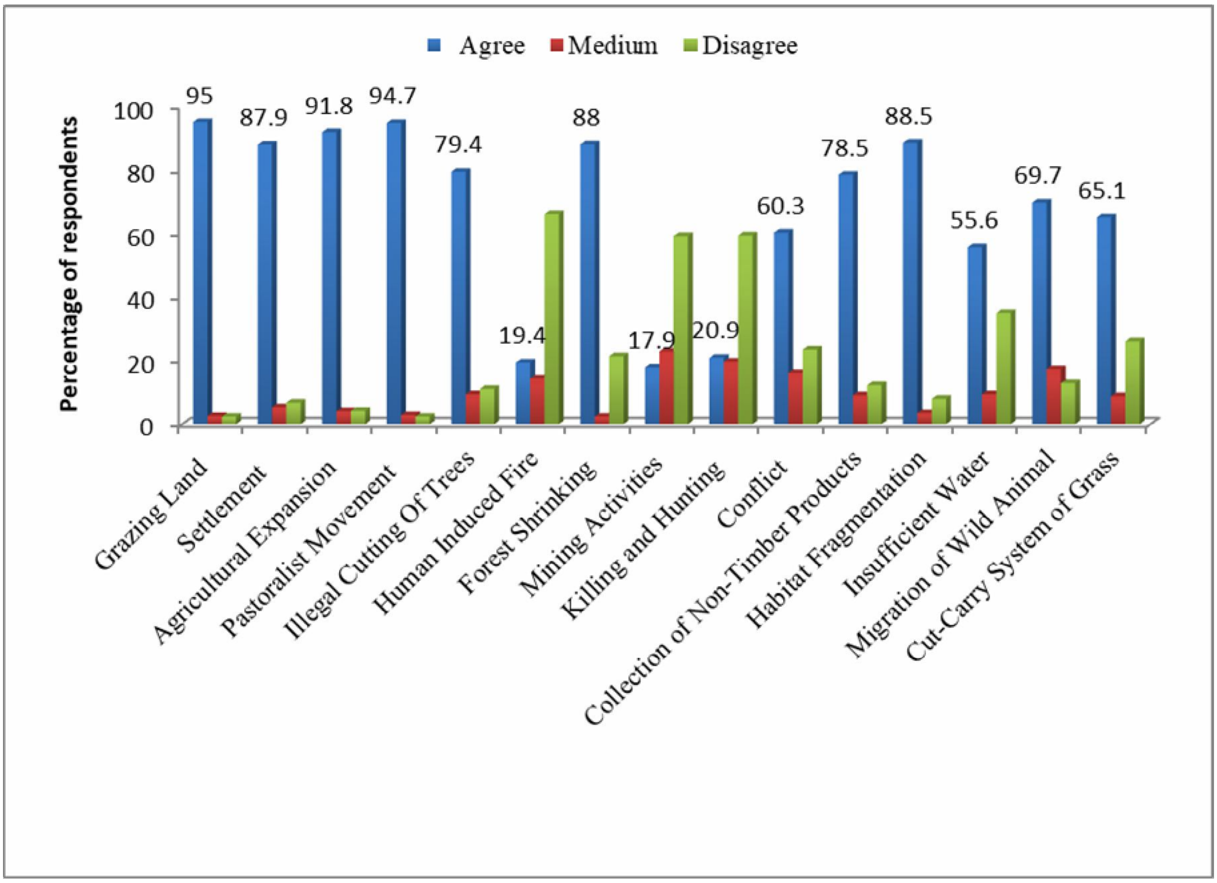


Figure 1. Causes of biodiversity degradation in Bale Mountains National Park of Ethiopia (adapted from Sefi et al (2017)).

***Carbon sequestration potentials of peatlands****.* The carbon stock of known peat reserves has been estimated at over 550 Gt, despite their low coverage of 3 % of the global land surface (Parish et al 2008). At the same time, new peat reserves are still being discovered in natural ecosystems, and not all peat soils in areas used for agriculture and forestry are recognized and/or recorded as such (Scharlemann et al 2014). Peatlands are estimated to hold about 1,500 tons of soil carbon per hectare that is about 10 times as much as a typical mineral soil (Epple et al 2016). For tropical peatlands, the values can be more than twice as high, depending on local topography and hydrological conditions (Parish et al 2008).

Carbon sequestration occurs relatively slowly in many types of peatlands with the notable exception of naturally forested peatlands, where biomass carbon plays a significant role (Parish et al 2008). For example, the average carbon accumulation rate for un-drained Finnish mire areas was 185 kg/ha/year, and that of peat domes in South East Asia was 313 kg/ha/year for Central Kalimantan and 770 kg/ha/year for coastal sites (Dommain et al 2011; Epple et al 2016). These figures are smaller than the sequestration rate of a fast-growing young forest stand (5 t C/ha/ year) and are quite comparable to that of tropical old-growth forest which is 490 kg/ha/year (Lewis 2009; Epple et al 2016).

The relevance of carbon sequestration in peatlands becomes greater as longer times are considered since peat accumulation can continue at the same rate for millennia if environmental conditions remain beneficial (Epple et al 2016). The rate of peatland disturbance has been steadily increasing leading to significant greenhouse gas emissions from the decomposition of organic matter in drained peat and peat fires (Parish et al 2008). Since 15 % of the global peatland area is disturbed (Parish et al 2008; Joosten 2015). Studies show that the average annual loss of peat carbon ranges from 0.3 to 2 GT/year, which accounts for more than 3 % of all anthropogenic carbon emissions (Epple et al 2016). Global hotspots of anthropogenic emissions from peatlands are Southeast Asia and Europe (Joosten et al 2012). The expected impacts of climate change on peatlands depend on the climatic zone as well as on-site conditions and may lead to an increase in emissions or enhanced sequestration, depending on location. Peatlands, where peat-forming vegetation is intact or has been restored, are likely to be more resilient to climate change impacts than degraded ones (Parish et al 2008).

***Carbon sequestration potentials of grasslands and savannahs***. Temperate, tropical, and subtropical grasslands and savannahs occur naturally over an area that covers about one-quarter of the world's terrestrial surface (Epple et al 2016). Besides, semi-natural grasslands have formed in many other regions where forests were cleared to create space for grazing livestock, covering another 15% of the Earth's landmass (Epple et al 2016). Due to their large area, grasslands play a significant role in the terrestrial carbon balance (Liu et al 2015). The total amount of carbon stored in the natural grassland biomes is 470 Gt (80% in soil), which is one-fifth of the carbon contained in terrestrial vegetation and topsoil worldwide (Trumper et al 2009; Ciais et al 2013).

Among the main processes influencing greenhouse gas emissions and sequestration in grassland ecosystems are habitat conversions to cropland, grazing by wild and domesticated animals, harvesting of the wood fire, and climate change (Liu et al 2015). Drylands affected by land degradation currently cover around 4-8 percent of the global land area, and that around 0.3 Gt C per year is lost from dryland soils as a result of unsustainable agricultural and pastoral practices (Joosten 2015). As projections show a continued rise in population growth and an increase in frequency and duration of drought in many dryland areas, it is expected that the vulnerability of grasslands to degradation will grow over the coming decades (Soussana et al 2013).

***Carbon sequestration potentials of mangroves, salt marshes and seagrass beds***. Coastal vegetation that is flooded by the sea can act as a trap for small particles of organic matter from the water column, which stores soil carbon for centuries or even millennia (Van Bochove et al 2014). Despite covering only about 50 million hectares (0.1% of the Earth's surface), these ecosystems prevent methane formation due to high salt and store carbon (Pendleton et al 2012). These ecosystems together have 11-25 Gt of a total carbon stored, which means they hold 0.5-1.2% of the world's biomass and topsoil carbon (Epple et al 2016).

Specifically, mangroves have the highest mean value of carbon per hectare; 150t C/ha in tree biomass and 320 t C/ha in soil (Van Bochove et al 2014), whereas, the mean carbon stocks in salt marshes and seagrass beds are 260t and 140t C/ha, respectively (Murray et al 2011). The respective average carbon sequestration rates of mangroves, salt marshes, and seagrass beds are 1.63 t, 1.51 t, and 1.38 t $CO_2$ eq/ha/year, respectively (Murray et al 2011). Finally, all of the three ecosystems are under high pressure from human activity, including conversion to agriculture, aquaculture, settlements or coastal infrastructure, pollution with excess nutrients and chemicals, and others (Van Bochove et al 2014).

As studies show, about 30 to 50% of these ecosystems are lost over the last century and the degradation continued by 1 to 2% per year, leading to annual global carbon emissions of 0.02-0.12 Gt by mangroves, 0.01–0.07 Gt by salt marshes, and 0.04–0.09 Gt by seagrass (Pendleton et al 2012). Besides, climate change poses an additional threat to coastal ecosystems, like sea-level rise and coastal defense structures together are likely to reduce the area that is available for natural coastal vegetation (Epple et al 2016). Another expected impact of climate change is a shift in the geographical distribution of mangrove and salt marsh habitat, as warmer temperatures allow mangrove vegetation to expand towards the poles and encroach on habitats currently occupied by salt marshes. Under undisturbed conditions, this shift in vegetation type is likely to lead to an increase in carbon storage capacity (Epple et al 2016).

***Carbon sequestration potentials of tundra ecosystems**.* Tundra ecosystems cover 10 % of the global land area, mostly in the northern hemisphere, and are characterized by peat-forming vegetation (Joosten 2015). Their role in the climate system is mainly determined by the fate of the large quantities of carbon stored in their soils, especially in the permanently frozen layers (Epple et al 2016). They are the largest reservoir of organic carbon worldwide since permafrost soils of the tundra and boreal forest zone together contain at least 1,700 Gigatonnes of carbon (Ciais et al 2013). There are serious concerns that tundra ecosystems will turn into a major source of greenhouse gas emissions within the next few decades, as climate change causes continued melting of the permafrost layer, and that this will lead to positive feedback further reinforcing climate warming (Ciais et al 2013; Joosten 2015).

Biomass carbon stocks in the tundra zone are expected to increase under climate change, as rising temperatures and changes in precipitation will continue to allow tall shrub and tree species to colonize the area (Epple et al 2016). However, most authors expect that these carbon gains will not be large enough to compensate for the losses in soil carbon. Pressures from human activity in tundra ecosystems are mostly linked to the extraction of fossil fuels and other mineral resources. Despite significant impacts on the Arctic environment, these activities are currently not considered to be a major driver of greenhouse gas emissions due to their limited spatial extent (Epple et al 2016).

***Carbon sequestration potentials of croplands**.* Croplands cover around 13% of the global land surface, mostly located in areas formerly covered by forests and grasslands (Epple et al 2016). Agriculture accounts for a significant share of global anthropogenic greenhouse gas emissions through the decomposition of soil organic matter and biomass, emissions of methane from livestock and rice cultivation, nitrous oxide from fertilizers and manure management, and others (Scharlemann et al 2014). The amount of carbon stored in cropland soils can vary considerably depending on management practices as well as local factors such as geology and climate (Epple et al 2016).

However, where local environmental conditions are comparable, soil carbon stocks are usually significantly lower in croplands than in other types of ecosystems. Land-use change from pasture to cropland resulted in an average decline of soil carbon stocks of more than 60%, which has reduced global soil organic carbon stocks by 40 to 100 Gt carbon (Scharlemann et al 2014; Joosten 2015). Due to the rising demand for agricultural products, it is projected that the use of existing croplands will be further intensified; potentially increasing the application of unsustainable methods, and intensive arable land uses will continue to expand into other ecosystems, especially savannahs and grasslands, tropical forests and peatlands (Van Bochove et al 2014). To meet the needs of food in 2050 by the current level, the production should be increased by 60%, which needs additional croplands of 320- 850 million hectares (Epple et al 2016).

***Carbon sequestration potentials of abandoned croplands**.* When croplands are abandoned, under most circumstances they will turn into carbon sinks because the carbon losses that took place following conversion are partly or fully reversed. For instance, most of 75 million hectares of cropland went out of use in Russia, Kazakhstan, Ukraine, and Belarus since 1990, which has reverted to forest and grassland ecosystems

(Epple et al 2016). However, it is to be expected that many abandoned areas will be returned to agricultural use in the coming decades.

**Conclusions**. It is widely recognized that improving how ecosystems are managed and used can be a key component in efforts to mitigate and adapt climate change. Therefore, the maintenance of existing natural carbon reservoirs worldwide is essential to capture and store carbon inside the body of biodiversity. Many works of literature show, there is a significant potential for cutting future emissions of greenhouse gases through maintaining healthy ecosystems and restoring degraded environments. Since different species have different primary productivity rate and nutrient consumption efficiency, the amount of carbon tied up by these species also vary. As a result, carbon stored in biodiversity is higher than the few species in disturbed ecosystems in general. Since data are scarce on the relationship between biodiversity and carbon sequestration, it is better if mega projects and researches are initiated worldwide to sustainably conserve ecosystems.

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