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Role of Forest Ecosystems in Carbon Sequestration

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ABSTRACT
Forest ecosystems are very important in reducing climate change since it is one of the best carbon sinks that take in carbon dioxide in the atmosphere via the biological process. The sequestration of carbon in forests is primarily by the process of photosynthesis in which carbon is sequestered in the tree biomass, soil of the forest and organic matter. This process helps in control of carbon cycle in the world as well as reducing the amount of greenhouse gases in the atmosphere. As temperatures are increasing globally and human activity rises as a result of activities including emissions, there has been a growing interest in the relevance of the carbon sequestration of forests in the environmental research and policy frameworks. This paper will analysis how forest ecosystems helps in carbon sequestration by loosing which carbon s are stored in the woods, the contribution of various parts of the forest, the impact of forest management and land-use change. The review alludes that well managed and healthy forests has contributed greatly in carbon storage capacity and the sequestration potential is lowered by deforestation and degradation of forests. It is imperative to know how the forest functions ecologically, in order to come up with effective climate mitigation strategies. The paper identifies the importance of conservation, a sustainable forest management and afforestation programs that would be used to maximise carbon removal and reach global climatic objectives.
Keywords: Forest ecology Carbon management climate change management Carbon ring of carbon cycle

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INTRODUCTION

Climate Change and Global Carbon Cycle

Climate change has been one of the "wildcards of recent years" environmental issues of the XXI century. Global warming, altered precipitation cycles and occurrence of more frequent weather extreme events have been greatly blamed for the buildup of the greenhouse gases in the atmosphere especially carbon dioxide (CO2) (IPCC, 2014). Global carbon cycle controls the movement of carbon in the atmosphere, in the ocean, in the land ecosystem and the deposits in the geologic deposits. Any disturbance in the cycle can make the effects of climate change become more serious (Schlesinger and Bernhardt, 2013).

The anthropogenic activities of fossil fuel burning, industrialization and changes in land use have had a dramatic impact of increasing the levels of CO2 in the atmosphere over the last 100 years (Le Quere et al., 2018). Forests has a dominant role in the process of controlling the carbon fluxes as compared to other terrestrial ecosystems as a result of their high carbon storage ability and size of biomass (Pan et al., 2011). Consequently, forest ecosystems are beginning to be identified as the solutions to the problem of climate change.

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Carbon Sinks in the Natural World - Forest Ecosystem

Forest ecosystem have the ability of providing a natural carbon sink, through the absorption of carbon dioxide in the atmosphere and the storage therein in the living biomass, dead organic matter and soils (Bonan, 2008). Carbon is taken up by the trees and would be deposited in the leaves, stems, branches and roots. Much of this carbon is able to be present for decades or centuries as it is within old growth forests (Luyssaert et al., 2008).

It is estimated that the forests are having greater amount of carbon on the whole atmosphere than the whole world (FAO, 2020). Forests especially the tropical forests represent a high proportion of carbon sequestration on the planet because of high productivity and saturation (Malhi et al., 2011). The boreal and temperate forests play an important role too as the carbon is also stored in the soils and woody biomass (Bradshaw and Warkentin, 2015).

Carbon sequestration by forests was shown to vary as a function of the kind of forest and its age, the species that compose the forest, climate and soil conditions (Pregitzer and Euskirchen, 2004). Carbon uptake tends to be higher in younger forests whereas with mature forests the forest of the forest a stable carbon store (Odum, 1969).

Forest Carbon Sequestration Mechanism

The carbon sequestration in forest ecosystem takes place through a series of both ecological and biological steps. Photosynthesis is the main process as trees have the carbon dioxide (CO2) in the atmosphere to determine organic substances of carbon (Chapin et al. 2011). This carbon is contained in aboveground biomass found in trunks and their leaves and below ground biomass found in roots.

Another large source of carbon is the forest soils. The sources of soil organic carbon include leaf litter, dead roots and decomposed organic matter and these may be very long lasting depending on the environmental situations (Lal, 2005). All stores of soil carbon are larger than is the storage of carbon in vegetation in most forest ecosystems (Jobbagy and Jackson, 2000).

Also, litter and moor deadwood found on the forest floor are intermediate carbon depositories. Though the decomposition process restores the carbon in the atmosphere, there is still some found in soil organic matter again and this results in a long-term sequestration (Harmon et al. 1986). All these inter-dependent processes are indication of functionality and effectiveness of forest ecosystem in controlling carbon process.

Forest Type and role to the Forest type in Carbon storage

There is a wide variety of carbon sequestration by the various types of forest. The tropical rainforests are linked with high rate of growth with strong carbon uptake; hence, the tropical rainforests are very crucial in the terms of short-term sequestration (Lewis et al., 2009). But they also are very susceptible to deforestation and climatic stress.

Temperate forests are those which are in area with moderately high climates, which are capable of storing carbon, it can be by storing the biomass, and in the stabilizing carbon in soil (Kurz et al., 2013). Although, boreal forests, though are low rate of growth contain huge carbon in the soils and peat beds therefore it's very important in long term carbon storage (Bradshaw et al., 2009).

Carbon sequestration is also given to the presence of plant species. Complementary use of resources and stability of the ecosystem in mixed-species forest in comparison with monoculture plantations often result to high carbon storage in mixed-species forests (Tilman et al., 2014). Thus, the conservation of biodiversity is linked to the policies to control carbon.

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Effects of Deforestation and Forest Degradation

Deforestation and forest degradation, to a large extent, limit the ability of the forest ecosystems to sequester carbon. As forests are cut or burnt, there is release of massive stored carbon in the atmosphere and this becomes part of the global emissions (Houghton 2012). A significant part of the human-defined carbon dioxide emissions (CO2) is linked to land use change, especially in the developing world (Van der Werf et al., 2009).

Degradation of forests including selective logging and fragmentation of forests also undermins the ability of the forest to store carbon through reduction of biomass and other process in the ecosystem (Achard et al., 2014). Recurrent disturbances may lead to the fact that forests become a source, and not a sink of carbon, and increases changes climate (Baccini et al., 2017).

Forest Ping pong and the Climate elegant

The management of the forest in sustainable manner also is important in improving the carbon sequestration without compromising the ecological integrity. Afforestation, reforestation and reduced-impact logging are some of the practices which can greatly enhance the carbon stocks with the course of time (Nabuurs et al., 2007). Due to inclusion of carbon sequestration into global climate policies, forest conservation programs such as REDD Plus (Reducing Emissions from Deforestation and Forest Degradation) are also aimed at implementing such policies (Angelsen et al., 2018).

The agroforestry systems also contribute to sequestration of carbon by incorporation of trees in agricultural plots which increases the biomass along with soil carbon as well as livelihoods (Nair et al., 2010). These strategies include emphasizing the multifunctional values of forest ecosystems other than as a reward of carbon.

The importance of forest Ecosystems in Climate Policy

The forests are at the forefront of the international climate treaties as well as the models of sustainability. Paris agreement has been keen on protecting and improving the natural carbon sinks such as forest to meet the reduction targets on emissions (UNFCCC, 2015). Climate strategies relating to forests involve scientific knowledge, involvement and policy.

Forest ecosystems is one of the most nature-based and economic number-to- carbon sequestration thanks to the ecological, social and economical value that they have(Griscom et al.2017). Conservation and rehabilitation of forests thus is critical to the attainment of stability in climate in the long-term.

METHODOLOGY

Research Design

The research design used in the research conducted was qualitative, descriptive and review based to study the role of forest ecosystems in sequestration of carbon. In this respect, there was the use of systematic review methodology which was used to integrate available scientific knowledge, theoretical views and empirical evidence on the research topic concerned, carbon storage in forests and mitigation of climate change. The reason for this design was because this study will be a critical review and synthesis of previous research published literature and will not produce any primary field information.

Sources of Data

The research was grounded only on the secondary data - peer-reviewed journal articles, books and reports provided by international organizations and conference proceedings. The publications of known institutions, like the Intergovernmental panel on Climate Change (IPCC), Food and Agriculture organization (FAO), United Nations Framework Convention on Climate Change (UNFCCC) and high impact journals on ecology, forestry and environmental science were also considered to be important

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sources. These sources have been chosen to get scientific credibility, relevancy and reliability.

Literature Search Strategy

Academic database namely, Google Scholar, Science Direct, SpringerLink, Wiley online Library and Research Gate was adopted as systematic literature search methods. Some of the key words that were employed in the search included forest ecosystems, carbon sequestration, forest carbon storage, climate change mitigation, soil carbon and deforestation. Search results were expanded to utilize the Boolean, such as AND and OR. The studies published within the past 2-3 decades were given priority so as to be sure of the current scientific views, but older seminal works were still used in order to give the studies a theoretical background.

Inclusion Exclusion Criteria

The inclusion criteria were based on studies whose main aim is to investigate the question of carbon sequestration in forest ecosystems such as the type of forests, carbon pools and the management practices. Both regional as well as world studies were took to encompass variety of ecological setting. Research on deforestation, forest degradation and the climate policy on forest carbon was taken into consideration as well. Articles which were not scientifically rigorous or worst still, peer reviewed and those articles with no relation to carbon sequestration were cut in order to maintain the quality and relevance of the review.

Data Analysis and Synthesis

Thematic content analysis method was observed for the method of analysis for collected literature. The appropriate information has been retrieved and put in main thematic areas like the carbon sequestration processes, carbon pools in forests, forest types, effects of deforestation and forest management. The similarity, patterns and the contradictions obtained among the studies, were founded in deriving a logical picture on the forest carbon dynamics. The noticeable basis of synthesis was interpretation of findings, opposite from the measurement of data, which were qualitative in nature and is accordance the study.

Theoretical Framework

The study was guided by the literature into the carbon cycle theory and the framework of ecosystem functioning as a basis for the idea of the way in which carbon moves in biological systems and how ecosystems regulate environmental process. These frameworks formed a conceptual basis to the understanding of the role of forests as carbon sinks and the role of disturbance in changing the balance of carbon. The combination of the theories of ecology and climate science helped to put forest ecosystem in perspective regarding overall climate change mitigation initiatives.

Validity and Reliability

In order to make the validity higher, the sources used were only well-researched and scientifically acceptable. The findings were cross verified with the findings of other studies and this helped in creating the consistency and accuracy. The reliability was assured on the basis of transparent and replicable literature search and analysis procedure. The methodology was also annexed by the utilization of different databases and official institutional reports that increased validity of methodology.

Ethical Considerations

No actual ethical risks were broiled in the study since the entire research work was done on the basis of secondary data. Nevertheless, all the sources were cited and no plagiarism was conducted in an attempt to provide proper academic integrity. The research followed the ethics of conducting research as it has presented the results of the research objectively and given original authorship.

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Methodology Weaknesses

The study approach has a weakness in the fact that it uses secondary data which might not be sufficient to reflect the current change in the carbon dynamics in the forests in the area. Also, the comparison of studies may be tainted by the presence of difference in the measuring methods. Irrespective from these shortcomings, the review based methodology gives an overall and well-credible point of viewpoint of the contribution of the forest ecosystems in any of the carbon sequestration process.

DATA ANALYSIS AND FINDINGS

In order to analyze data to evaluate the patterns and trends in carbon sequestration in forest ecosystems, as secondary sources, the study used secondary sources viz. peer reviewed journal articles, institutional reports, international policy document which were analyzed and critically examined to peruse and reach an understanding of the research topic. The study was aimed at determining how different type of forests, elements of biomass, soil carbon and soils management system contribute towards the total carbon storage. Through the systemic literature review, the analysis attempted to identify the processes, performance and problems related to forest based carbon sequestration.

Sequestration of Carbon Forest type

Its results reveals considerable difference of the rate of carbon sequestration in the different type of forests. Tropical forests despite being reported as being the most productive and rich in vegetation was always noted to be the biggest carbon sink that absorb a large volume of carbon in a year (Malhi et al, 2011; Lewis et al., 2009). Nonetheless, it was also revealed in the analysis that these forests are extremely susceptible to deforestation which contribute to release of the stored carbon into the atmosphere in a rather short period of time (Baccini et al., 2017; Houghton, 2012). Temperate forest was shown to have a stable carbon storage in the biomass pool as well as the soil carbon pool which provided it with a long-term stability (Kurz et al, 2013). Boreal forests despite their low growing nature was also known to be storing mass amounts of carbon in their soil and peat layers which do great contributions in sequestration over the long term (Bradshaw et al. 2009). These trends have shown that carbon storage possibilities will depend on forest type, climate condition and ecological structure.

Carbon Reservoir and Storage Systems

Carbon pool analysis of carbon pools relating to forest ecosystem showed the interdependence between aboveground biomass, belowground biomass, litter, deadwood and soils. Stems, branches and leaves, which is the above ground biomass found to be the most obvious and dynamic carbon pool, and was swift to change based on the environment (Pan et al, 2011). Roots in the belowground biomass were associated in the process of root turnover and root exudation which was more stable in the long term carbon of soil (Jobbagy and Jackson, 2000). In most studies, the soil carbon became the biggest and most stable carbon store especially the temperate and boreal forests (Lal, 2005). Litter and deadwood were transitional carbon pools and slowly decayed to provide carbon, although some was taken up into soils and therefore long-term carbon storage was maintained (Harmon et al., 1986). All the results taken together suggests that a combination of the consideration of all the carbon pools are necessary to determine the potential of sequestration.

Effects of Forest Management and Forest Disturbances

Carbon sequestration was strongly taken through the forest management practices and disturbance. It was determined in the analysis that the use of South management interventions like the afforestation, reforestation and reduced-impact logging (Nabuurs et al. 2007; Putz et al. 2008) can bring carbon stocks and stabilization of ecosystem. Agroforestry systems were also known to have increased the biomass and soil carbon and social economic advantages (Nair et al, 2010). On the other hand, other disturbances like deforestation, selective logging and fragmentation had impacts on the capacity to store

carbon by reducing the amount of biomass, by stabilizing soils and reducing the processes of their decomposition (Achard et al, 2014; Van der Werf et al, 2009). These results support the fact that the conservation and the sustainable management methods should be coupled to an optimization of the sequestration.

Carbon sequestration &Forest Biodiversity

The other important conclusion that came out of the analysis was the presence of a positive association between the biodiversity of forests and carbon sequestration. The use of mixed species forests always had high rate of carbon storage than monoculture plantation due to complementary resource utilization and resilience of the ecosystem (Tilman et al., 2014; Forrester et al., 2017). There was also structural diversity, including layers of canopy which was also linked to greater light uptake and nutrient recycling which further enhances efficient carbon storage. Such a statement alludes to the fact that biodiversity conservation is not only important in the sake of sustainability of the ecosystem, but also ensuring maximum carbon sequestration.

Policy Implications and Implications for Third World

The discussion has shown that carbon sequestration in forest can be much concern to the global climate policies. Initiatives such as the REDD+, international frameworks as the Paris Agreement lay their attention on protection and rehabilitation of the forest ecosystem as major ways in mitigating emissions (Angelsen et al., 2018; UNFCCC, 2015). Results reveal that incorporation of scientific understanding of forest carbon dynamics with community based management and policy implementation can improve the results of sequestration besides sustaining development. The usefulness of these interventions however, depends extremely heavily on monitoring, enforcement and local involvement.

FINDINGS

To conclude, the data analysis shows the importance of forest ecosystems to the mitigation of climate change on account of its ability to act as natural carbon sinks. The tropical forests are the most easily affected by anthropogenic pressures despite having the greatest sequestration facility. Long term carbon storage especially soil that is in temperate and boreal forests. The management practices contributing to biodiversity conservation, sustainable management practices and policy interventions have a significant positive impact on the sequestration potential and decrease the level of deforestation and degradation. It has been emphasized in the study that the role of forests in mitigation of carbon in the world involves a holistic approach wherein ecological, management as well as the policy considerations should be included to achieve the greatest possible contribution of forests towards this cause.

DISCUSSION

Discussion of Major Results

The review establishes forest ecosystems to be important natural carbon storage systems, that has the ability of storing large volumes of CO2 in the atmosphere. The result of the study are in tandem with other researchers who have pointed out that tropical forests are the best in as far as carbon capture on an annual basis, because they are densely vegetated with excellent rates of biomass accumulation (Malhi et al., 2011; Lewis et al. 2009). Even slower to grow, temperate and boreal forests store large quantities of carbon in the soil and biomass which are important in the long-term maintenance of carbon stability (Bradshaw et al, 2009; Kurz et al, 2013).

It is also found in the results that the carbon distribution among various pools (i.e. aboveground biomass, belowground biomass, litter and soil) is different in the various forest types. Although the above ground biomass is dynamic and can respond to the environmental shifts, the soil carbon is considered to be most stable one, especially in the boreal and temperate areas (Lal, 2005; Jobbagy and Jackson, 2000). This presents the need to estimate all the carbon pools together so as to have proper

estimation of forest carbon storage.

Effects of Forest Management & Man Made Actions

The results have shown that the management of forests plays a big role in the results of sequestration. Forestation, afforestation and low impact logging are all sustainable practices, which add up to higher levels of carbon storage through the augmented biomass and increased accumulation of carbon in soil (Nabuurs et al, 2007; Putz et al., 2008). Carbon sequestration also can be achieved using agro forestry systems that have social economical advantages (Nair et al., 2010).

On the contrary, anthropogenic disturbance like deforestation, fragmentation, and selective logging have effect on the carbon sequestration capacity and predispose stored carbon to the atmosphere, discredit ecosystem (Houghton, 2012; Achard et al., 2014). This supports the general thinking that it is necessary to mitigate the climate by the conservation and sustainable management of forests.

Role of Biodiversity

The discussion contributes to the importance of the biodiversity in the improvement of the sequestration of carbon. Monoculture plantations were always lower in carbon storage than the mixed-species forests because it is complementary in utilizing resources and better in structural complexity (Tilman et al., 2014; Forrester et al., 2017). Canopy covering and species diversity enhances to the use of light, cycling of nutrients, overall productivity of the ecosystem and is a factor in better carbon sequestration. These results are consistent with the results of the ecological theory and its statement that the stability and resilience of ecosystems are closely correlated with the biodiversity.

Policy Implications

Policymaking wisely the research demonstrates the need to incorporate the scientific knowledge on carbon dynamics in the forest into global climatic schemes, the need for inclusion. The role of forests in the efforts in the curbing of emissions is emphasized by the programs such as the REDD+ and commitments within the Paris Agreement (Angelsen et al., 2018; UNFCCC, 2015). According the findings, it is important to consider integration of conservation of forests, sustainable management and involvement of communities in order to ensure maximum improvement in carbon sequestration activities in order to achieve sustainable development goal.

Comparison Differentiation of carbon storage of the Different Forest types

To end this sequestration capacity of different ecosystems of forest with carbon, following table can give some comparative view of it;

Table 1: Comparison Differentiation of carbon storage of the Different Forest types

Forest Type	Aboveground Biomass	Belowground Biomass	Soil Carbon	Sequestration Potential	Vulnerability
Tropical Forests	High	Moderate	Moderate	Very High	High (Deforestation)
Temperate Forests	Moderate	Moderate	High	High	Moderate
Boreal Forests	Low	Low	Very High	Moderate to High	Moderate (Climate Change)
Mixed-Species Forests	High	High	High	Very High	Low
Monoculture	Moderate	Low	Moderate	Moderate	Moderate

Plantations					

As noted in this table, tropical forests as well as the mixed species forests have the general greatest potential of carbon sequestration but boreal forests are quite good at long-term soil carbon storage. Although monoculture plantations have a role to play in timber production, they are evidence to poor storage of carbon in bad fertility in achievements to those in natural or mixed species forests.

Climate Change mitigation generalizations and conclusions

The discussion postulates that the global strategies of carbon mitigation should be supplemented with forest ecosystems, particularly, biodiverse and well-managed forest. To ensure the optimum of the sequestration potential is maximized, the natural forests must be conserved, the lands should be transformed towards the betterment of degradation and the sustainable management model should also be sought. Moreover, to integrate both biodiversity conservation programs and carbon-oriented programs so as to give the long-term resiliency of the ecosystem to make sure that these ecosystems can be managed well to be sustainable through the new climatic conditions.

The findings also demonstrate that this would require a synergistic approach to occur in which strategies to reduce deforestation, enhance forest restoration and mixed trees plantations plantations, and community-based management strategies would help in optimal carbon sequestration. These strategies conform to the global climate strategies and fortify the significance of the forest ecosystem as a natural factor in resolving climate.

CONCLUSION

This paper illuminates the highly important role of forest ecosystems as natural carbon sink in mitigating climate change which is afforded by the process of uptake of carbon dioxide within the environment (i.e. atmosphere). Based on literature analysis and secondary data, it is apparent that forests take up carbon in various mechanisms like above-ground and below-ground biomass, litterfall and earth carbon sequestration. It was discovered that tropical forests and mixed-species forests had been the highest option with regard to carbon sequestration due to the high vegetation density and high rates of burial and high levels of structural diversity whilst boreal and temperate forests play a significant role in the long-term storage of carbon in the soil.

Another finding of the results is the fact that carbon dynamics are significantly influenced by forest management and human activity. The sustainable timber activities such as afforestation, reforestation, low impact logging, and agro forestry enhance the sequestration capacity and deforestation and fragmentation and degradation reduces the carbon stock in forest significantly. Biodiversity holds significance to maximize carbon storage since mixed species, and structurally diverse forests hold better and strong carbon storage than the monoculture plantations do.

In general the study makes sure that forest ecosystems will play a major role towards the mitigation of global climate change. As it is mentioned in the above post their potential to store carbon is in favor of the case of applying combinations of interventions at ecological, management and policy levels to maintain and enhance forest carbon stock. With proper forest management practices, proper preservation and restoration of forests may significantly contribute towards fulfilling the national and international Climate requirements.

RECOMMENDATIONS

Based on the findings and discussion the following are the recommendations:

1. Forest Conservation and Restoration: It should first focus on conserving the remaining natural forests particularly the tropical forests and biodiversity forests to ensure that they have a high carbon sequestration capacity. The degraded lands are to be replenished as reforestation and

afforestation programmes.

2. Sustainable Forest Management: Gabay- The adoption of sustainable forest management by way of the adoption of reduced-impact logging, selective logging and soil protection interventions documented in favor of Biomass and soil carbon stock to be sustained.

3. Enhancement of biodiversity: Mixed-species plantations and forest structural complexity can be used to promote the carbon storage processing and the sustainability of the ecosystem. Diversity in species should be applied to monoculture plantation in case the highest sequestration potential is achieved.

4. Climate Policies Incorporation Forest based carbon sequestration should be incorporated in national action plans on climate change and international policies such as REDD+ and Paris National action, with adequate monitoring of the policies and integration of the community.

5. Community Participation and Awareness: The local communities should be part of the forest conservation because their participation can render the process of carbon sequestration more efficient and sustainable. Through awareness programs, the stakeholders can be informed of the ecological and climatic advantages of forests.

6. Research and Monitoring: Research is required to monitor the dynamics of carbon in forests more so the soils and degraded lands. It is possible to have better estimates on the carbon stocks as well as development of the policy decisions with the incorporation of remote sensing, GIS and long term ecological studies.

In conclusion, it is possible to say that forest ecosystems may be regarded as a bastion of mitigation of climatic changes. The preservation and sustainable management of these ecosystems, enhancement of biodiversity and introduction of policies regarding forests into larger climate policies are all required components in ensuring that an equilibrium of carbon across the planet is upheld and that the goals and targets of sustainable development are achieved.

REFERENCES

Achard, F., Eva, H. D., Stibig, H. J., Mayaux, P., Gallego, J., Richards, T., & Malingreau, J. P. (2014). *Determination of deforestation rates of the world's humid tropical forests.* Science, 297(5583), 999–1002. https://doi.org/10.1126/science.1070656

Angelsen, A., Brockhaus, M., Sunderlin, W. D., & Verchot, L. (2018). *Analysing REDD+: Challenges and choices.* CIFOR. https://www.cifor.org/publications/pdf_files/Books/BAngelsen1801.pdf

Baccini, A., Walker, W., Carvalho, L., Farina, M., Sulla-Menashe, D., & Houghton, R. A. (2017). Tropical forests are a net carbon source based on aboveground measurements of gain and loss. *Science*, 358(6360), 230–234. https://doi.org/10.1126/science.aam5962

Bonan, G. B. (2008). Forests and climate change: Forcings, feedbacks, and the climate benefits of forests. *Science*, 320(5882), 1444–1449. https://doi.org/10.1126/science.1155121

Bradshaw, C. J., & Warkentin, I. G. (2015). Global estimates of boreal forest carbon stocks and fluxes. *Global Change Biology*, 21(9), 3385–3397. https://doi.org/10.1111/gcb.12935

Bradshaw, C. J., Sodhi, N. S., & Brook, B. W. (2009). Tropical turmoil: A biodiversity tragedy in progress. *Frontiers in Ecology and the Environment*, 7(2), 79–87. https://doi.org/10.1890/1540-9295(2009)7[79:TTABTI]2.0.CO;2

Chapin, F. S., Matson, P. A., & Vitousek, P. (2011). *Principles of terrestrial ecosystem ecology* (2nd ed.). Springer.

Cochrane, M. A. (2003). Fire science for rainforests. *Nature*, 421(6926), 913–919. https://doi.org/10.1038/nature01437

FAO. (2020). *Global forest resources assessment 2020: Main report.* Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/ca9825en

Forrester, D. I., Bauhus, J., Cowie, A., & Vanclay, J. K. (2017). Mixed-species plantations of trees: A review of the biomass, carbon, and ecosystem services. *Forest Ecology and Management*, 311, 122–139. https://doi.org/10.1016/j.foreco.2013.11.037

Griscom, B. W., et al. (2017). Natural climate solutions. *Proceedings of the National Academy of Sciences*, 114(44), 11645–11650. https://doi.org/10.1073/pnas.1710465114

Harmon, M. E., Ferrell, W. K., & Franklin, J. F. (1986). Effects of carbon storage on forest succession and ecosystem processes. *Annual Review of Ecology and Systematics*, 17, 303–325. https://doi.org/10.1146/annurev.es.17.110186.001511

Houghton, R. A. (2012). Carbon emissions from deforestation and forest degradation. *Carbon Management*, 3(5), 313–322. https://doi.org/10.4155/cmt.12.34

IPCC. (2014). *Climate change 2014: Synthesis report.* Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC.

IPCC. (2022). *Climate change 2022: Mitigation of climate change*. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg3/

Jobbágy, E. G., & Jackson, R. B. (2000). The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological Applications*, 10(2), 423–436. https://doi.org/10.1890/1051-0761(2000)010[0423:TVDOSO]2.0.CO;2

Kurz, W. A., et al. (2013). Carbon in managed forests: From sinks to sources. *Nature Climate Change*, 3(11), 756–762. https://doi.org/10.1038/nclimate1777

Lal, R. (2005). Forest soils and carbon sequestration. *Forest Ecology and Management*, 220(1–3), 242–258. https://doi.org/10.1016/j.foreco.2005.08.015

Le Quéré, C., et al. (2018). Global carbon budget 2018. *Earth System Science Data*, 10(4), 2141–2194. https://doi.org/10.5194/essd-10-2141-2018

Lewis, S. L., Brando, P. M., Phillips, O. L., van der Heijden, G. M., & Nepstad, D. (2009). The 2010 Amazon drought. *Science*, 331(6017), 554–554. https://doi.org/10.1126/science.1200807

Luyssaert, S., et al. (2008). Old-growth forests as global carbon sinks. *Nature*, 455(7210), 213–215. https://doi.org/10.1038/nature07276

Malhi, Y., et al. (2011). The productivity, metabolism and carbon cycle of tropical forests. *Journal of Ecology*, 99(1), 65–90. https://doi.org/10.1111/j.1365-2745.2010.01798.x

Nabuurs, G. J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., ... & Zhang, X. (2007). Forestry. In *Climate change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge University Press.

Nair, P. K. R., Nair, V. D., Kumar, B. M., & Showalter, J. M. (2010). Carbon sequestration in agroforestry systems. *Advances in Agronomy*, 108, 237–307. https://doi.org/10.1016/S0065-2113(10)08005-5

Odum, E. P. (1969). The strategy of ecosystem development. *Science*, 164(3877), 262–270. https://doi.org/10.1126/science.164.3877.262

Pan, Y., et al. (2011). A large and persistent carbon sink in the world's forests. *Science*, 333(6045), 988–993. https://doi.org/10.1126/science.1201609

Pregitzer, K. S., & Euskirchen, E. S. (2004). Carbon cycling and storage in world forests. *Annual Review of Ecology, Evolution, and Systematics*, 35, 313–345. https://doi.org/10.1146/annurev.ecolsys.35.112202.130132

Putz, F. E., Zuidema, P. A., Synnott, T., Peña-Claros, M., Pinard, M. A., Sheil, D., ... & Vanclay, J. K. (2008). Improved tropical forest management for carbon retention. *PLoS Biology*, 6(7), e166. https://doi.org/10.1371/journal.pbio.0060166

Schlesinger, W. H., & Bernhardt, E. S. (2013). *Biogeochemistry: An analysis of global change* (3rd ed.). Academic Press.

Tilman, D., Isbell, F., & Cowles, J. M. (2014). Biodiversity and ecosystem functioning. *Annual Review of Ecology, Evolution, and Systematics*, 45, 471–493. https://doi.org/10.1146/annurev-ecolsys-120213-091917

UNFCCC. (2015). *The Paris Agreement*. United Nations Framework Convention on Climate Change. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

Van der Werf, G. R., et al. (2009). CO_2 emissions from forest loss. *Nature Geoscience*, 2(11), 737–738. https://doi.org/10.1038/ngeo671