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Principles and Ways to Enhance Forest Carbon Sink Under the Background of Carbon Neutrality

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Abstract

Reducing atmospheric CO_2 content and mitigating climate warming has become a frontier hot issue of widespread concern in the scientific community and the international community. There are many options for achieving "carbon peak and carbon neutral", among which forestry carbon sequestration is an important way to play a fundamental, strategic, and unique role in addressing global climate change. The enhancement of forestry carbon sink potential is a process of regulating the balance of net carbon budget in the forest ecosystem, mainly including the regulation principles of plant fixation of inorganic carbon (photosynthesis process, net productivity, etc.), turnover and fixation of soil organic carbon (decomposition of animal, plant and microbial residues and clay fixation), etc. The author expounds the main principles, methods or ways of improving forest carbon sink from the perspective of forest carbon sink. The main ways to enhance the potential of forest carbon sink include:

(1) The first way to increase forest carbon sink is to increase forest area.

(2) Strengthening the scientific management and fine management of forests to increase forest net productivity is the core of improving forest carbon sink.

(3) Prevent forest diseases and insect pests and forest fires to avoid reducing forest net productivity.

(4) Use mineral clay to protect organic carbon to increase forest soil carbon sink.

(5) Protect forest resources, always adhere to the concept of harmonious development between human beings and nature, and increase forest area through suitable sites, trees, and artificial afforestation.

Keywords: Carbon neutralization; forest carbon sink; carbon sequestration.

1. Introduction

Over the years, climate change has gradually evolved into a global issue, forcing the world to study it to explore targeted measures to solve the problem. Existing research can clarify the uncertainty of climate change, but researchers believe that preventive measures can have a certain impact. Trutnevyte et al. (2019) proposed that climate change is not just a field of research, but should be based on the establishment of climate models, encouraging scientists

from different fields to conduct interdisciplinary learning and research, and jointly develop reasonable, feasible, and effective solutions to climate challenges. In addition, they called on countries around the world to participate in the cause of addressing climate change, and countries should not be left out. To alleviate this problem, two approaches can be taken: carbon emission reduction and carbon sequestration. At present, both of them have become the focus of research by scientists. The main research directions for carbon emission reduction are adjusting the energy structure and researching and developing clean energy; In the field of carbon sequestration, researchers believe that the ability of biomass to fix carbon dioxide should be explored to achieve greater carbon sequestration.

The terrestrial ecosystem mainly absorbs CO_2 through photosynthesis and fixes it in vegetation and soil to regulate regional carbon cycle and maintain global ecological balance. One of the core contents of global change research is the carbon cycle at global and regional scales, and climate change is also affected by carbon cycle feedback (LU et al., 2018). The terrestrial ecosystem fixes 1/3 of the carbon in the atmosphere, and different types of terrestrial ecosystems have different carbon capture capacities. The area of forest and grassland ecosystems accounts for more than half of the land ecosystem. At least 40% of global soil carbon is stored in forest ecosystems and 10%~30% is stored in grassland ecosystems (Li et al., 2021). The area of agricultural ecosystem accounts for 38.5% of the terrestrial ecosystem, and it is the most active carbon pool in the carbon cycle process of the terrestrial ecosystem. The universality of agricultural activities and the remarkable dual attributes of carbon fixation and carbon release have aroused widespread concern of scholars at home and abroad in carbon cycle research (Lv et al., 2019). Although wetlands account for the least area, they still occupy a place in the terrestrial ecosystem carbon cycle with their ultra-high carbon fixation efficiency. To sum up, forests have enormous application value for carbon storage. Therefore, various departments should strive to improve forest carbon sinks in the context of carbon emission reduction policies (Mu et al., 2013). The forestry department believes that there are two key directions for improving forest carbon sinks, one is to protect forest biodiversity, and the other is to improve energy efficiency (Sepp ä l ä et al., 1998; Yang et al., 2019). This also reflects the importance of forest carbon sinks. Therefore, studying the factors that affect forest carbon sinks plays an important role in improving forest carbon sinks (Singh et al., 2011).

2. Method: literature review

2.1. Principle of improving forest carbon sink

Forest carbon sink includes forest plant (including living/dead trees) biomass carbon and soil (including surface litter and mineral soil layer) organic carbon. The level of carbon sink depends on the carbon turnover rate (reciprocal of turnover cycle) and carbon input and output (Fang et al., 2021). In a balanced ecosystem, input equals output. The carbon input of forest comes from its net productivity, which is mainly represented by the growth of biomass and the annual production of litter. The carbon output of forests is mainly reflected in the harvest of raw materials of forest products and the output of CO_2 and soluble organic carbon (DOC) from the decomposition of animal, plant and microbial residues (YANG et al., 2022). In a balanced forest ecosystem, the turnover rate is the ratio of carbon input to carbon sink (YANG et al., 2022). The net productivity and harvesting age of forests, especially the input and turnover rate of forest soil carbon, have a significant impact on forest carbon sinks. Therefore, we want to improve forest carbon sink, that is, increase forest plant biomass carbon and soil organic carbon.

2.2. Ways to improve forest carbon sequestration

2.2.1. Increase afforestation area

Forest biomass carbon is proportional to forest area, so the first way to increase forest carbon sink is to increase forest area. The global terrestrial ecosystem has a net carbon sequestration of 60 Pg per year (PAN et al., 2013). In 2020, the global forest area will be 4.06 billion hm2 (FAO, 2018), forest carbon sequestration accounts for up to half of the carbon sequestration of the entire terrestrial ecosystem (PAN et al., 2013), so the average carbon sequestration of global forests will be about 7.4 t/(hm2. a). If the forest area is increased by 3.4%, the carbon fixation amount of 1 Pg can be increased every year.

On the contrary, cutting down forests and planting crops or economic forests will reduce forest carbon sinks. Ten years after the conversion of forest land into agricultural land, the soil organic carbon decreased by 30.3% on average, becoming the carbon source of the atmosphere (Li et al., 2016). Compared with temperate and cold zone forests, the carbon storage of tropical rainforest vegetation is higher, the frequent occurrence of deforestation in tropical rainforests has also led to significant carbon emissions, accounting for 20% of global greenhouse gas emissions.

2.2.2. Increase forest net productivity

Strengthening the scientific management and fine management of forests to increase forest net productivity is the core of improving forest carbon sink. Proper irrigation or fertilization can increase the net productivity of forests and achieve the goal of increasing carbon sequestration of forests. Also on a global scale, an increase of 3.4% in forest net productivity can generate an additional 1 Pg of carbon sequestration each year. The net productivity of tropical forests is twice that of temperate forests (PAN et al., 2013). Increasing the net productivity of tropical forests can effectively reduce atmospheric CO_2 content. The latest research shows that compared to a single pure forest, in addition to providing a richer habitat environment and more effectively preventing the occurrence of diseases and pests, the biomass is also significantly higher than that of pure forest, with an average increase of 25.5% (FENG et al., 2022). Therefore, focusing on the construction of mixed forests is also one of the important ways to increase forest carbon sink.

In order to effectively improve forest carbon sequestration capacity, forest management can adopt afforestation and reforestation to renew forest resources. Afforestation refers to the conversion of wasteland into forest land for artificial tree planting and planting or natural seeding. Reforestation is to convert the land originally covered by forest but damaged by natural or human factors into forest land after later planting and seeding or natural seeding. That is, replanting or supplementary planting of forest land within a large space between trees, so as to promote the regeneration of forest trees and improve the forest carbon sink capacity (Chen, 2018).

In addition, the amount and capacity of fixed carbon of forests are closely related to the life and business cycle of forest trees. The longer the natural life of forest trees, the longer their carbon dioxide fixation time, and the carbon fixation amount and carbon fixation capacity will gradually improve. Therefore, managers related to forest management can cultivate long-lived trees with a long growth cycle, which can continuously strengthen the vitality of forest resources, thus increasing carbon storage. When managing forests, we should maximize the cultivation of forest tree species and the replacement of tree species, focusing on the cultivation of basically formed tree species and top tree species. At the same time, we should accelerate the transformation of pioneer tree species, so as to cultivate and manage high-quality forest trees and promote the sustainable development of forest resources (Xiang, 2021).

2.2.3. Prevention of pests and diseases and fire to reduce the loss of forest net productivity

Forest diseases and pests often reduce forest net productivity. The loss of forest net productivity can also be reduced through chemical, physical and biological control of pests and diseases. When pests and diseases break out, the loss can often reach 5%~20% of the forest net productivity (Hu, 2019). Different pest damage modes and mechanisms are different (CHI, 2022). At the stand level, leaf loss usually leads to a decrease in carbon storage (Jing et al., 2016); Leaf pests directly affect photosynthesis by eating leaves or absorbing juice to destroy chlorophyll; Stem borers such as bark beetles kill trees and turn forests from carbon pools to carbon sources. Kurz et al. of the Natural Resources Agency of Canada (KURZ et al., 2008) published shocking research results in the journal Nature by calculating the impact of the mountain pine caterpillar epidemic on the pine forests of British Columbia: in the worst years of pest damage, the affected forests have become a large source of CO_2 emissions, and its total carbon emissions are 3/4 of the carbon emissions caused by Canadian fires.

Forest fire reduces forest carbon sink. Strengthening the monitoring of forest fires and reducing fires can reduce the loss of forest net productivity (He, 2021). Disturbance causes a large area of forest loss, which is an important factor affecting forest carbon flux (Tian et al., 2003) and one of the main sources of global greenhouse gases (Hu et al., 2013). In 2019, there was a serious forest fire in Australia. High temperatures and drought caused the forest fire to rage for several months, and the area of forest burning exceeded 80000 km².

2.3. Ways to increase soil organic carbon content

According to Zhou's research (Zhou et al., 2004,2008,2013; Huang et al., 2011; Xiong et al., 2020,2021), external environmental changes (such as global temperature rise, N deposition, acid deposition, etc.) do not play a leading role, that is, endogenous driving process. Under the endogenous drive, the source of soil organic carbon increases with the increase of forest maturity. Even in the zonal forest stage, there is much higher source of soil organic carbon than that of immature forests.

Changes in the external environment (such as global temperature rise, N deposition, acid deposition, etc.) can not only directly affect the dynamics of soil organic carbon, but also regulate the dynamics of soil organic carbon by changing the driving factors such as the water and heat status of the ecosystem, the quality of plant residues (such as C/N ratio, lignin content), and plant diversity. The former is obviously an exogenous driven process, and its basic characteristics should be that it plays a role in both immature and mature ecosystems, but there are exceptions; The latter is difficult to be directly classified as exogenous drive, because the natural succession of the ecosystem will also cause changes in these driving factors, that is, internal and external combined drive.

Therefore, we can increase soil organic carbon from the following aspects. The global soil data shows that the higher the soil clay content, the higher the soil organic carbon content (ZHOU et al., 2005). The decomposition of plant residues can form small particle size organic matter, but most of the small size organic matter comes from microbial residues. Microbes first decompose plant residues, and then produce new microbial residues after death. 50%~80% organic carbon in mineral soil layer is microbial residue carbon (LIANG C et al., 2019). In other words, the important way to increase soil carbon sink is to increase the amount of microbial residues in the soil with high clay content.

Underground carbon input from plant roots is more conducive to the formation of microbial residual carbon than aboveground litter input, and is more stable (JIA S X et al., 2022). Therefore, it can be considered to bury the litter on the forest land surface into the soil, and then cultivate microorganisms in the mineral soil layer. The resulting microbial residues can be directly protected by soil clay particles, so as to increase the fixation of soil organic carbon and increase the soil carbon sink. For example, every 1-3 years, plough and dig ditches (about 30 cm deep) between the rows of trees in the already closed forest land, and bury the dead branches and fallen leaves of adjacent plants. If the operation measures are implemented in the soil with wet expansion and dry shrinkage or the area with alternate freezing and thawing, the protection effect of clay will be doubled; This business measure is also very suitable for areas where mechanized operations can be carried out.

In humid areas, it can be considered to plant nitrogen fixing plants between tree rows, which is conducive to increasing the number of earthworms. Earthworms are cultivators of forest soil, which contribute to the formation of soil organic matter and clay particle complexes. One kind of endogenous earthworms lives in the mineral soil layer but feeds on the surface litter layer, which can bury the surface plant litter into the soil and increase the soil carbon fixation effect. In relatively dry areas, termites and ants that nest underground also have similar carbon fixation effects (BONACHELA J A et al., 2015). Therefore, protecting soil biodiversity and increasing the number of earthworms, ants and other animals can promote the fixation of soil organic carbon.

This requires doing a good job of protecting forest resources, adhering to the balanced development of human beings and nature, and achieving the goal of harmonious development of ecological civilization. The harmonious development of man and nature should not only protect forests, but also maintain ecological balance and promote the unified and harmonious development of human, nature and society (Yuan, 2019). Therefore, when carrying out forest management, relevant managers should take a broad view of the overall situation. While doing well in forest management, construction and management, they should also strengthen the concept of forest carbon sequestration, strengthen publicity and guidance, so that people can be aware of the role of forest resources in promoting sustainable social development and the positive role of improving forest carbon sequestration capacity in protecting the natural ecological environment. Improve the consciousness of human and society on forest resources protection, thereby improving the forest carbon sink capacity and promoting the harmonious development of humans, nature and society.

3. Conclusion

In order to achieve the carbon neutral vision and control CO_2 emissions, this article focuses on the carbon storage

capacity of forests, and specifies that to enhance forest carbon sinks, it is necessary to increase forest plant biomass carbon and soil organic carbon. By elaborating on the principles of enhancing forest carbon sinks, suggestions for improving forest carbon sinks are proposed.

(1) Forest biomass carbon is proportional to forest area, so the first way to increase forest carbon sink is to increase forest area. If the forest area is increased by 3.4%, the carbon fixation amount of 1 Pg can be increased every year. On the contrary, cutting down forests and planting crops or economic forests will reduce forest carbon sinks.

(2) Strengthening scientific management and fine management of forests to increase forest net productivity is the core of improving forest carbon sink. Proper irrigation or fertilization can increase the net productivity of forests and achieve the goal of increasing carbon sequestration of forests. Managers related to forest management can cultivate long-lived trees with a long growth cycle, cultivate and manage high-quality forest trees, and promote the sustainable development of forest forest resources.

(3) Forest diseases and pests often reduce forest net productivity. The loss of forest net productivity can also be reduced through chemical, physical and biological control of pests and diseases. And forest fire reduces forest carbon sink. Strengthening the monitoring of forest fires and reducing fires can reduce the loss of forest net productivity.

(4) The important way to increase soil carbon sink is to increase the amount of microbial residues in the soil with high clay content. It can be considered to bury the litter on the forest land surface into the soil, and then cultivate microorganisms in the mineral soil layer to increase the fixation of soil organic carbon, so as to increase the soil carbon sink. Protecting soil biodiversity and increasing the number of earthworms, ants and other animals can promote the fixation of soil organic carbon.

(5) Protect forest resources, adhere to the concept of harmonious development between man and nature, and achieve the goal of harmonious development of ecological civilization. The harmonious development of man and nature should not only do a good job in forest protection, but also maintain ecological balance and promote the unified and harmonious development of human, nature and society.

Reference

[1] BONACHELAJ A, PRINGLE R, SHEFFER E, et al. (2015). Termite mounds can increase the robustness of dryland ecosystems to climatic change[J]. Science, 347:651-655. DOI:10.1126/science.1261487.

[2] Chen H B. (2018). Effect of forest management on forest carbon sequestration and its improvement strategy[J]. Flowers and Plants, 2018(12):200-201.

[3] CHI J L, FAN Y K, WANG L J, et al. (2022). Retention of soil organic matter by occlusion within soil minerals[J]. Rev Environ Sci Biotechnol, 21:727-746. DOI:10.1007/s11157-022-09628-x.

[4] FAO. (2018). Global Forest resources assessment 2020 [EB/OL]. [2022-08-301]. http://www.fao.org/forest-resources-assessment/en/.

[5] FENG Y H, SCHMID B, LOREAU M, et al. (2022). Multispecies forest plantations outyield monocultures across a broad range of conditions[J]. Science, 376(6595):865-868. DOI:10.1126/science.abm6363.

[6] HE X. (2021). Influence of fire on forest ecological environment and carbon emission[J]. Low Carbon World, 11(1):221-222. DOI:10.16844/j. cnki.cn10-1007/tk.2021.01.109.

[7] Huang Y H, Li Y L, Xiao Y, et al., (2011). Controls of litter quality on the carbon sink in soils through partitioning the products of decomposing litter in a forest succession series in South China[J]. For Ecol. Manag., 261(7):1170-4177. DOI:10.1016/j.foreco.2010.12.030.

[8] HU H Q, WEI S J, SUN L, et al. (2013). Interaction among climate change, fire disturbance and ecosystem carbon cycle[J]. Arid Land Geogr., 36(1):57-75. DOI:10.13826/j.cnki.cn65-1103/x.2013.01.017.

[9] HU R R. (2019). Establishment and verification of forest pest based index model[D]. Beijing: Chinese Academy of Forestry, DOI:10.27625/d.cnki.gzlky.2019.000075

[10] JIAS X, LIU X F, LIN W S, et al. (2022). Tree roots exert greater influence on soil microbial necro mass carbon than above-ground litter in subtropical natural and plantation forests[J]. Soil Biol Biochem., 173:108811.

DOI:10.1016/j.soilbio.2022.108811.

[11] JING T Z, DOU X J. (2016). Impact and mechanism of insect pests on forest carbon sequestration[J]. World For Res, 29(1):29-35. DOI:10.13348/j.cnki.sjlyyj.2016.0002.y.

[12] KURZ W A, DYMOND C C, STINSON G, et al. (2008). Mountain pine beetle and forest carbon feedback to climate change[J]. Nature, 452(7190):987-990. DOI:10.1038/nature06777.

[13] LIANG C, AMELUNG W, L EHMANN J, et al. (2019). Quantitative assessment of microbial necro mass contribution to soil organic matter[J]. Glob Chang Biol, 25(11):3578-3590. DOI:10.1111/gcb.14781.

[14] LI N Y, ZHENG X X, LI J L, et al. (2016). Study on the assessment indicator system for carbon sink city[J]. For Resour. Manag., 2016(4):1-4. DOI:10.13466/j.cnki.lyzygl.2016.04.001.

[15] LI W, Huang M, Zhang Y D, et al., (2021). Temporal and Spatial Dynamics of Carbon Storage and Carbon Fixation Rate in China's National Forest Parks[J]. Journal of Applied Ecology, 32(3): 799-809.[16] LU F, HU H F, SUN W J, et al. (2018). Effects of national ecological restoration projects on carbon sequestration in China from 2001 to 2010[J]. Proceedings of the National Academy of Sciences of the United States of America, 115(16): 4039-4044.

[17] Lv S H, Zhang X P. (2019). Analysis on spatio-temporal evolution characteristics of agricultural net carbon sink in Shandong province [J]. Journal of Soil and Water Conservation, 33(2): 227-234.

[18] Mu, S., Cambrollé, J., Luque, T., Niell, F.X., (2013). Greening an approach to the evaluation and management of natural carbon sinks: From plant species to urban green systems. Urban Forestry Urban, 12, 450–453, https://doi.org/10.1016/j.ufug.2013.06.007.

[19] PAN Y D, BIRDSEY R A, PHILLIPS O L, et al. (2013). The structure, distribution, and biomass of the world's forests[J]. Annu Rev Ecol Evol Syst, 44:593-622. DOI:10.1146/annurev-ecolsys-110512-135914.

[20] Singh, V.S., Pandey, D.N., Prakash, N.P., (2011). What determines the success of joint forest management? Science-based lessons on sustainable governance of forests in India. Resour. Conserv. Recycl. 56 (1), 126–133, https://doi.org/10.1016/j.resconrec.2011.09.015.

[21] TIAN X R, SHU L F, WANG M Y. (2003). Direct carbon emissions from Chinese forest fires, 1991-2000[J]. Fire Saf Sci, 12(1):6-10.

[22] Trutnevyte, E., Hirt, L.F., Bauer, N., Cherp, A., Hawkes, A., Edelenbosch, O.Y., van Vuuren, D.P., (2019). Societal transformation dynamics in models for energy, climate and environmental policy: the ambitious next step. One Earth, Under Revi., 15–17 https://doi.org/10.1016/j.oneear.2019.12.002.

[23] Xiang Y. (2021). Measures to improve forest carbon sequestration capacity in forest management[J]. Modern Agricultural Science and Technology, 2021(20):125-126.

[24] Xiong X ,Zhou G Y, Zhang D Q, (2020). Soil organic carbon accumulation modes between pioneer and old-growth forest ecosystems[J]. J Appl Ecol., 57(12):2419-2428. DOI:10.1111/1365-2664.13747.

[25] Xiong X, Liu J X, Zhou G Y, et al., (2021). Reduced turnover rate of topsoil organic carbon in old-growth forests: a case study in subtropical China[J]. For Ecosyst, 8:58. DOI:10.1186/s40663-02100337-5.

[26] Yang, Y., Reilly, E.C., Jungers, J.M., Chen, J., Smith, T.M., (2019). Review Climate Benefits of Increasing Plant Diversity in Perennial Bioenergy Crops. One Earth 1(4), 434–445. https://doi.org/10.1016/j.oneear.2019.11.011.

[27] Yuan Q. (2019). Impact of forest management on forest carbon sink and its improvement measures[J]. Agriculture and Technology, 39(19):62-63.

[28] Zhou G, Morris J, Zhou C, et al., (2004), Hydrological processes and vegetation succession in a naturally forested area of Southern China[J], Eurasian J For Res, 7(2) : 75-86.

[29] Zhou G Y, Guan L L, Wei X H, et al., (2008). Factors influencing leaf litter decomposition: an intersite decomposition experiment across China[J]. Plant Soil, 311(1/2):61-72, DOI: 10.1007 /s11104-008-9658-5.

[30] Zhou G Y, Peng C H, Li Y L, et al., (2013). A climate change induced threat to the ecological resilience of a subtropical monsoon evergreen broad Heaved forest in Southern China[J]. Glob Change Biol, 19(4):1197-4210. DOI:10. 111/gcb.12128.

[31] ZHOU L, LI B G, ZHOU G S. (2005). Advances in controlling factors of soil organic carbon[J]. Adv Earth Sci, 20(1):99-105. DOI:10.3321/j.issn:1001-8166.2005.01.016.