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Regional Optimization of Forest Management Strategies in China: Suggestions for Maximizing Carbon Sequestration while Limiting Environmental Trade-offs

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Abstract

To limit anthropogenic climate change, enhancing natural carbon sequestration through strategic forest management practices is grave, beyond solely reducing greenhouse gas emissions. China's forest area, estimated at 220 million hectares in 2022, ranks fifth globally and encompasses a wide range of forest ecosystems, climates and soils, with great potential for carbon sequestration through the implementation of region-specific forest management strategies. However, uncertainties persist in quantifying the effects of environmental factors (e.g., soil properties, regional climate and altitude) on the net carbon accumulation of different forest management strategies. Filling this research gap is grave for optimizing region-specific forest management practices that avoid unintended trade-offs. Here, we synthesize existing research, focusing on reforestation, afforestation and natural forest regrowth in China. Reforestation displayed the highest area-weighted carbon accumulation rate (mean ± standard deviation=4.4 ± 3.84 Mg C ha^{-1} yr^{-1}), followed by afforestation (2.765 ± 2.44 Mg C ha^{-1} yr^{-1}) and natural forest regrowth (2.576 ± 2.82 Mg C ha^{-1} yr^{-1}). Furthermore, the relatively high standard errors in the sequestration potential for all three strategies indicated significant variability in effectiveness due to regional environmental differences. On the basis of our findings, we present region specific recommendations for forest management strategies in China to achieve win-win solutions for climate modification and additional ecosystem services.

Keywords: Forest management; Soil organic carbon; Nature-based solutions; Active and passive restoration; Carbon sequestration

Introduction

The Paris climate agreement includes a goal of maintaining global warming below 1.5°C above pre industrial levels to avoid existential environmental changes, which world leaders and scientists argue needs to be achieved before the end of the century (Global warming of 1.5°C IPCC, 2020) [1]. To achieve this ambitious goal, in addition to reducing anthropogenic Greenhouse Gas (GHG) emissions, the implementation of land-based climate modification pathways is important for enhancing natural carbon sequestration. Land-based modification solutions or Natural Climate Solutions (NCSs) can be divided into twenty different pathways, mainly categorized into forest pathways, grassland and agriculture pathways and wetland pathways. In terms of modification potential, NCSs could be used to alleviate CO_2 levels by 37% and are cost effective, with a 66% chance of limiting warming to below 2°C [2]. However, uncertainty still persists regarding how to best optimize specific modification strategies and how regional environmental factors impact the efficacy of modification approaches for carbon sequestration. Thus, further research is needed to identify regional modification pathways that are tailored to maximize carbon sequestration while avoiding potential trade-offs with local environmental resources. To ensure the scalability needed to meaningfully combat climate change, the cost of implementation of these modification pathways must be minimized.

Land-based modification strategies are particularly important for achieving China's ambitious climate goals [3]. China is the second largest economy in the world, the largest emitter of GHGs and a developing nation, meaning that the country must meet a growing electricity demand while simultaneously reducing GHG emissions [4]. To address this unique challenge, China aims to become carbon neutral before 2060 by restructuring the current economy while altering the system of energy production to reduce GHG emissions (World Resources Institute, 2021) [5]. However, the current policies and programs are insufficient to limit global warming to 1.5°C, necessitating additional land management approaches to close this gap [6]. While climate modification solutions are urgently needed in China, a long-term climate modification plan should maximize climate benefits and minimize unintended consequences such as soil degradation and the depletion of water resources.

Here, we investigate and review the suitability of land-based modification programs and policies that could be applied regionally in China. Synthesizing the results of past studies, we summarize the benefits and trade-offs of different methods and compare the carbon sequestration potential of different forest management strategies. Furthermore, we consider the environmental factors that vary regionally and control the response size of the Soil Organic Carbon (SOC) level following forest management. The objectives are to provide a basis for the future regional implementation of the NCS policy and an evaluation reference for future studies of land-based modification solutions.

Materials and Methods

Overview of forest management strategies

Forests play a grave role in providing climate modification services. Trees capture and sequester atmospheric carbon dioxide as they grow through the process of photosynthesis [7]. In fact, the photosynthesis of plants is the most feasible and promising carbon capture method considering both its efficiency and cost. Through transforming atmospheric carbon dioxide into organic carbon molecules and sequestering them in biomass, forests have high potential for justifying the growing problem of climate change. According to the latest IPCC report (Sixth Assessment Report IPCC, 2022), adaptations for natural forests include conservation, protection and restoration, which require sustainable forest management [8]. The forest management pathway can support over two-thirds of the NCS modification needed to limit warming to below 2°C, is cost effective and reduce CO_2 levels by approximately half. Notably, grave climate-modification services can be provided by upscaling CO_2 removal to achieve negative net emissions through the enhancement of natural carbon sinks in ecosystems. In addition to climate modification benefits, forest management is vital for sustaining wildlife and biodiversity while providing food, fuel and timber to society. Forest management can be subdivided into forestation (reforestation and afforestation), forest conversion avoidance, natural forest regrowth and wood fuel avoidance.

Forestation involves large-scale artificial tree planting and is considered one of the most important land-based strategies for climate modification [9]. As with most forest pathways, forestation also has beneficial effects on ecosystems, including on biodiversity, air filtration, water filtration, flood control, soil fertility, etc. Forestation can be further divided into two subtypes: Reforestation and afforestation. Reforestation refers to managing the conversion of previously forested land back to a forest ecosystem, which is essential for restoring and promoting ecosystem functions while combating climate change. In comparison, afforestation involves the planting of trees in regions where there is currently and historically no tree cover, with the objectives of improving soil quality, avoiding desertification and reducing atmospheric CO_2 levels.

Since 1999, China has launched a reforestation project known as the Grain for Green Program (GGP), which aims to improve the ecological environment and transform low-quality farmland into forest and grassland. Degraded farmland that is susceptible to soil erosion has been identified and the GGP has aided in transforming 28 million hectares of cropland and barren scrubland back to forest to prevent erosion while alleviating rural poverty [10]. With the implementation of the GGP, Chinese provinces, such as Qinghai province, experienced a consistent increasing trend in the total annual Normalized Difference Vegetation Index (NDVI) from 1995 to 2020, along with an increase in the Ecosystem Service Value (ESV) of 6.8% [11]. Similarly, the Three-North Afforestation Program (TNAP), which was launched in 1978 and is planned to last until 2050, is considered one of the largest ecological afforestation projects on Earth. Spanning 551 counties across 13 provinces in Northeast China, the intervention region covers more than 42% of China's land area. Through large-scale afforestation to increase forest coverage, the goals of the 73-year TNAP plan are to alleviate desertification, control soil and water loss and conserve biodiversity. In terms of the effect of this program, an increase of 47.06 TgC per year in the capacity of the overall carbon sink was estimated with the implementation of an afforestation strategy [12].

However, limitations persist, as the forestation of arable land can result in trade-offs with local food production. Forests tend to require large quantities of water, so new plantations can decrease soil moisture and the volume of renewable freshwater resources [13]. Even though more forestation has occurred in China than in the rest of the world combined, uncertainties still persist regarding the trade-offs of such efforts. For example, people have planted trees to allay desert expansion in the northern region, but this effort has depleted local water resources and degraded soils, as the plant species are ill suited to dry climates. In the southern region, reforestation practices with monocultures are a threat to reducing local biodiversity (Forests and climate change | MIT Climate Portal, 2021) [14].

Another method of forest management is natural forest regrowth, which is the recovery of forest cover in cleared land areas through natural succession after the cessation of previous disturbances or land use. Forestation involves carefully planned tree planting to avoid negative outcomes such as inappropriate species selection, whereas natural forest regrowth may cost less and better promote the re-establishment of local biodiversity [15]. In addition to lowering costs, previous research has indicated that artificial restoration through the planting of trees does not result in consistently faster or more complete recovery than that at passively restored sites; thus, simply ending certain types of land use is sufficient for forests to recover in many cases [16]. In China, the National Forest Protection Program (NFPP) was launched in 1998 to protect natural forests and improve the ecological environment by banning commercial logging and relocating forest employees with subsidies and social services. According to previous field studies, until 2017, the forest cover in the provinces impacted by the Nedspice Farmers Partnership Programme (NFPP) increased by an average of 172.4%, which was significantly greater than the increase of 63% for the provinces without intervention. In contrast to forestation programs, which are water resource intensive, the NEPP contributes to soil and water retention while enhancing carbon sequestration and restoring wildlife habitats [17]. However, the potential for natural forest regrowth is limited, as bans on timber harvesting inevitably increase the import of large amounts of wood products from other countries, which may have negative effects on the forests in other countries and regions [18].

Forest management strategies, which are either implemented actively or passively, aim to increase the carbon sequestration capacity of terrestrial ecosystems by increasing vegetation coverage. However, while artificial restoration programs, such as afforestation and reforestation, can result in the unintended depletion of freshwater and soil carbon resources, natural forest regrowth is limited by severe land degradation and a lack of seed sources. Despite their potential for extensive carbon sequestration and habitat restoration, different types of forest management strategies should be implemented regionally to minimize these trade-offs.

Comparison of active *vs.* passive forest restoration

Although the goal of various forest management strategies is to upscale CO_2 removal by restoring natural forest ecosystems, these methods differ and can be divided into active and passive restoration strategies. Passive restoration processes involve strategies such as natural forest regrowth, where the reestablishment and recovery of forest ecosystems rely on the spontaneous regrowth of trees and vegetation after previous disturbances. Restoration involves the natural process of gradual environmental succession and artificial intervention is limited except for the cessation of environmental stressors, such as those associated with agriculture or grazing [19]. In contrast, active restoration involves the implementation of management techniques such as the planting of seeds or seedlings. Forestation, which involves large-scale tree planting, is an effective active management approach for enhancing biomass carbon stocks and providing additional ecosystem benefits.

As both active and passive restoration methods are nature-based solutions for forest pathways, evaluating the rate of carbon sequestration provides an opportunity for a quantitative comparison of scheme. In this study, a total of 27 data points related to the yearly area-weighted carbon sequestration rate of different forest management schemes were collected from 23 studies conducted the over the last 25 years, with 9 data points for each of the three forest management strategies (For specific details on the data collected, Refer to Figures S1-S3 in the Supplementary Information).

Some of the studies were conducted in a single country or region, such as China, India, Thailand, Australia, the Latin American tropics, the Amazon region, the mid-western U.S, Canada, Germany and Mediterranean islands, whereas other studies presented results that are global averages from measurements made across multiple regions [20-28].

Here, we describe the results from the regional studies described below. In terms of regional analysis, Australia has a high potential for forestation, as indicated by data from previous studies of reforestation and afforestation [28-36]. In India, reforestation programs for converting cropland into forest showed greater carbon sequestration potential than a natural forest regrowth scheme [37,38]. The values from China were significantly lower than those obtained regionally or globally, around 0.99 Mg C ha^{-1} yr^{-1} for reforestation, 0.12 Mg C ha^{-1} yr^{-1} for afforestation and 1.54 Mg C ha^{-1} yr^{-1} for natural forest regrowth.

Overall, reforestation displays the highest average sequestration potential, with a mean of 4.40 ± 3.84 Mg C ha^{-1} yr^{-1} (mean ± standard deviation) (Figure 1).

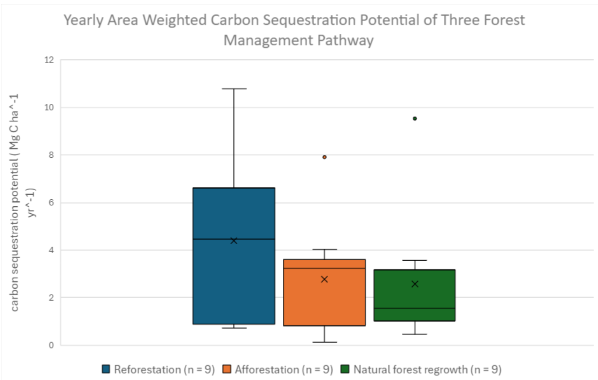

Figure 1: Distribution of the carbon sequestration potential data for reforestation, afforestation and natural forest regrowth.

Afforestation and natural forest regrowth exhibit similar sequestration potentials of 2.77 ± 2.44 Mg C ha^{-1} yr^{-1} and 2.58 ± 2.82 Mg C ha^{-1} yr^{-1}, respectively. The significant advantage of reforestation in carbon sequestration potential may derive from the environment of its intervention. As it is implemented in locations that are historically forested, the replanted trees have the access to sufficient soil conditions and water resources, as well as an environment that is suitable for promotion the development of new forests. In comparison, afforestation programs often aim to moderate desertification, which may result in high mortality rates for trees in the early stages of the reforestation process due to soil erosion or drought. For natural forest regrowth, the process of natural succession is time-consuming and generally has a lower overall sequestration potential than forestation programs do. The data for reforestation cover a broader range with a higher mean value, while the distributions are similar for the afforestation and natural forest regrowth data. Considering that the sample size was 9 for all three management schemes and that all the schemes were applied in different countries, with 2-3 globally measured datasets in each case, reforestation is associated with greater variability than other methods when implemented in different environments.

Nevertheless, our results for reforestation and natural forest growth (4.4 and 2.576 Mg C ha^{-1} yr^{-1}) are lower than the results reported by (Griscom et al., 2017) (8.945 and 3.58 Mg C ha^{-1} yr^{-1}). This variation may be due to the relatively smaller sample size, leading to low precision in representing the worldwide carbon sequestration potential of these forest management strategies [36]. However, the result still provides a quantitative comparison across the three forestation pathways, pointing out the advantage of reforestation for deeper analysis.

Qualitatively, forestation has beneficial effects on ecosystems, such as enhanced biodiversity, water filtration, flood control and soil fertility. With respect to reforestation efforts, since the implementation of the GGP from 1995 to 2020 in Qinghai Province, China, the observed total NDVI and additional ecosystem service levels have continued to increase locally. According to Yu Hu et al., the overall observed ecosystem value increased by 7.76% after the implementation of the GGP, where ecosystem services refer to various irreplaceable environmental conditions for socioeconomic development and ecosystem functionality. Afforestation programs such as the Three-North Afforestation Program (TNAP) also provide environmental benefits for qualifying desertification, controlling soil and water loss and conserving biodiversity. In addition, compared to that of other methods, the shorter duration of active restoration may require selective cutting, which can generate carbon stocks and simultaneously provide economic output from timber products. On the other hand, passive restoration through reliance on natural forest regrowth while limiting natural disturbances can effectively support tree establishment in native grasslands [39]. Compared with forestation, which inevitably involves careful planning to avoid negative outcomes such as inappropriate species selection, the spontaneous regrowth of plant species can gradually rejuvenate a well-established ecosystem. Although the process of natural succession necessitates a considerable amount of time, existing reviews suggest that naturally re growing forests can recover as well as or better than actively restored forests [40].

Soil Organic Carbon (SOC) levels and factors controlling SOC levels following forest management intervention

Carbon, as a constituent of all organic compounds, is essential for life on Earth. Carbon circulates in various forms in nature through different fluxes and is sequestered in different pools in nature. This whole process of circulation is known as the carbon cycle. In 1789, Antoine Lavoisier established the law of conservation of mass, which states that mass is not created or destroyed in chemical reactions [41]. In other words, the initial mass of any element in any isolated system always remains the same after any chemical reaction occurs. When applied to the carbon cycle, the delicate balance between the carbon stock circulating between the atmosphere and terrestrial carbon pools such as the soil and ocean can be revealed. The carbon cycle involves the concepts of fluxes and pools, where pools represent different stocks of sequestered carbon and fluxes are the rates of movement of carbon molecules between different pools. Within each pool, the carbon source is the input of carbon and the carbon sink is the amount of carbon output.

The forest soil-carbon pool is one of the largest natural carbon reservoirs and plays a pivotal role in regulating the circulation of the carbon cycle. Soil Organic Carbon (SOC) is the carbon sequestered in soil derived from plant or animal material decomposed by microbes. As a component that supports the stability of the soil structure and acts as a nutrient hub, SOC supports the habitat of soil organisms and their activity. In natural forests, SOC plays a major role in regulating soil health and providing other ecosystem services, such as biodiversity conservation and food production [42]. In terms of NCSs, SOC can be adjusted to restore land-based carbon pools as carbon sinks and lessen atmospheric CO_2 levels in response to predicted land-use change [43]. Therefore, the forest SOC level also serves as an indicator of the effectiveness of forest ecosystems for modifying global climatic warming.

Forest management strategies, such as forestation or natural forest regrowth, can significantly increase above the ground carbon sequestration in biomass from the atmosphere, but an increase in biomass does not necessarily lead to immediate or long-term increases in SOC storage [44]. For example, the increase in carbon uptake by biomass in the context of rising atmospheric CO_2 levels can be partially offset by the accelerated loss of soil carbon, as it stimulates microbial decomposition [45]. Soils are inherently dynamic and global change and management can alter how much carbon is stored in the soil and how it is distributed across different depths or functionally distinct pools [46]. According to the meta-analyses in previous studies, depending on the distinct environmental conditions, SOC stocks can either increase, decrease or remain unchanged after the implementation of forest management strategies, which can be complicated by many factors [47]. In China, researchers have reported that the response of SOC to different forest management strategies largely depends not only on climatic factors but also on the edaphic variables of the soil itself [48].

Air temperature and rainfall amount are two important climatic factors to consider when discussing differences in the regional environment. The variation in the SOC level underground is closely related to annual precipitation and the air temperature, which directly influence the soil temperature and pH [49]. Although plant production is generally high in environments with high mean annual temperatures, increases in temperature also accelerate microbial activity [50]. This imbalance between organic carbon material inputs by vegetation and the amount of carbon released *via* microbial decomposition, which is usually high, results in a net reduction in SOC stocks [51]. Moreover, in regions with very cold climates, such as tundra, where soil at depth is frozen year-round, soil drainage can be limited.

In terms of the amount of rainfall, when mean annual precipitation increases, it promotes the production of vegetation and contributes to the return of large amounts of litter and roots to the soil, which results in an increase in the response of SOC stocks [52]. In addition, in wet climates in which the soil pH is low, the soil can remain waterlogged for some portion of the year, retarding the microbial decomposition of SOC stocks. As part of the GPP launched in China, researchers have conducted meta-analyses of the effects of forestation programs on local SOC levels. Considering only climatic factors, the analyses revealed that the response size of the SOC stock was highest when the mean annual temperature was <9°C and the response size was roughly the same at temperatures from 9°C to 14°C and >14°C. The highest response of the SOC stock to the annual precipitation level was between 450mm and 550 mm and there was a significant decline in response size above or below this level.

Edaphic variables refer to the conditions and properties of soil that can affect the fauna, flora and microbial organisms living in a particular root zone or landscape. In terms of the influence on the SOC level, the major variable is the Initial SOC (iSOC) quantity sequestered through litter from vegetation and the exudation of plant roots. Many studies have shown that forest management strategies such as forestation usually only increase the SOC density in soils that initially have low carbon concentrations, whereas they may significantly decrease the SOC density in C-rich soils, especially in deep soils [53]. A high potential for rebuilding SOC stocks in croplands is also largely associated with the generally low initial SOC level observed in degraded cropland areas. Low SOC stocks, observed in initial C-rich soils after forestation, may be the result of high initial soil C losses that are stimulated by increased microbial respiration associated with site preparation in the early stage of forestation [54]. In northern China, researchers have concluded that the Soil Organic Carbon Density Threshold (SOCD) is approximately 10.5 ± 0.17 kgC m^2. In soils where the Soil Organic Carbon Density (SOCD) is lower than 5 kgC m^2, the SOCD increased for all plant species following forestation. In comparison, when the SOCD was above 15 kgC m^2, the SOCD tended to decrease after the implementation of the forestation strategies. The changing effect of the initial SOC level may also reflect that previous studies in which a fixed biomass/SOC ratio was assumed may have resulted in the overestimation of SOC stocks promoted by forestation-based management.

Regional climate of china

In China, owing to its geological and environmental conditions, the eastern region is dominated by a monsoon climate with dry winters and hot summers, whereas the western part of the country is characterized by continental, plateau and mountain climates. In eastern China, the subtropical monsoon climate is distributed between 25°C–35°C north and south, whereas the temperate monsoon climate is distributed between 35°C–55°C north. The rainy season in a subtropical monsoon climate is generally longer than that in a temperate monsoon climate. The northern and northwestern regions of China have a temperate continental climate, in which the temperature varies greatly annually and daily, with low humidity, partially due to their long distance from the ocean. Finally, for the plateau and mountain climates in the southwestern region, the high mountainous area is characterized by significant vertical variations in climate, affecting the diversity of vegetation; the region is characterized by low temperatures, strong radiation with abundant sunshine and low precipitation. According to the study performed by Qiquan Yang et al., China's climate zones can be specifically divided into five different types (Figure 2).

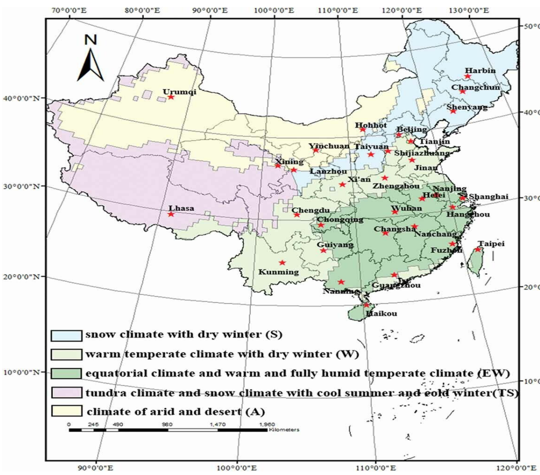

Figure 2: Locations of the 32 major cities and five climatic zones in China. The climatic zones are based on the classification of (Yang et al., 2017) [55].

In this study, the monthly temperature and precipitation data from 22 different cities, each in different provinces across the five different climate zones, were referenced from Climate-Data.org (China climate: Average temperature, weather by month & weather for china) [56]. The resulting monthly temperature and precipitation data are displayed in Figure 3.

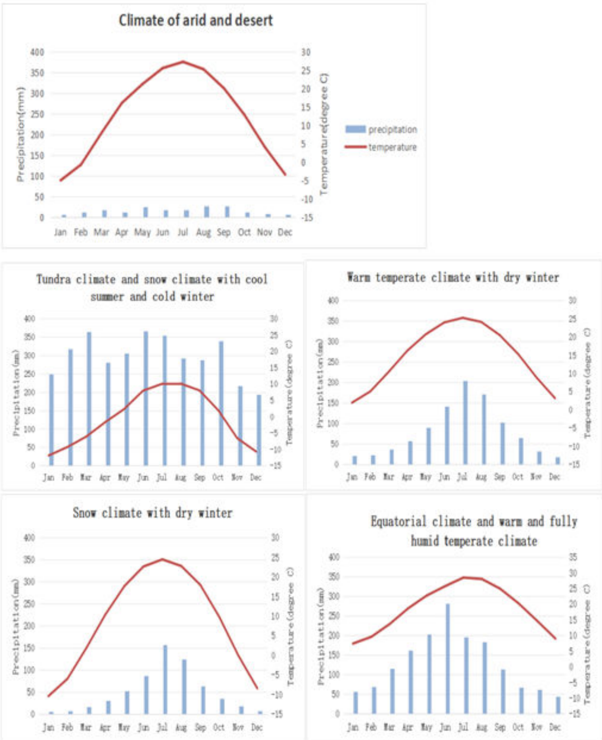

Figure 3: Monthly temperature and precipitation trends in the five different climate zones. The red line represents the temperature measured in °C and the blue bars represent the precipitation totals measured in mm. (China climate: Average temperature, weather by month & weather for china).

Through side-by-side comparisons, observations can be made regarding the climate variations in the five different climate zones. This research can reveal the potential threat of natural disasters such as droughts, which may occur in arid and desert climate regions, or flooding, which may occur in tundra and snowy climates. However, our sample sizes for the desert and tundra climates were smaller than those for the other three climate zones, thus may not fully represent the climate conditions in those two regions.

Using monthly temperature and precipitation data, the climate zone that is most suitable for forest management, considering the effect on the SOC level after strategy implementation, can be identified. On the basis of the annual temperature and precipitation in the five climate zones, we observe that the snowy climate zone, which is in northeastern China, is characterized by an annual temperature of 8.54°C, which is slightly less than 9°C and corresponds to the threshold of maximum SOC response reported by. The desert climate zone and warm temperate climate zone have annual temperatures of 12.62°C and 14.6°C, respectively, with similar responses in terms of the SOC level after forest management. The equatorial climate zone has an annual temperature of 18.55°C, whereas the tundra climate zone has a temperature of -0.51°C. These zones are least suitable for reforestation because their annual temperature is much higher or lower than the target threshold.

In addition, the annual precipitation in the snowy climate zone is 605.25 mm and among the five climate zones, it is closest to the optimal range of 450 mm–550 mm reported by. For the warm temperate climate zone and equatorial climate zone, annual precipitation averages 963 mm and 1556.44 mm, respectively, which are higher than the optimal range of precipitation for enhanced SOC accumulation. The total annual precipitation in the desert climate zone is 187 mm, indicating the potential threat of drought. The annual precipitation in the tundra climate zone is 3565 mm, which is significantly greater than the favorable range of precipitation for forestation.

Results and Discussion

In this study, we compared the sequestration potentials of three different forest management strategies and analyzed the environmental factors that influence the response of SOC to optimize the carbon sinks in both biomass and the soil. According to the comparison between active and passive restoration measures, active strategies such as reforestation and afforestation are expected to be more effective for enhancing the overall carbon sink. The implementation of active forestation may require prolonged supervision to avoid unintended disruptions to soil moisture or renewable freshwater resources [57]. In comparison, natural forest regrowth requires careful and sufficient consideration in selecting the species in the early stages of planning to promote the re-establishment of local ecosystems.

Annual temperature and precipitation are the two main environmental factors assessed in this study. China was divided into five climate zones and the average temperature and total precipitation in each climate zone were calculated to identify the optimal region for forest management. The results revealed that the annual temperature and precipitation in the snowy climate zone both reached the target threshold for maximizing SOC accumulation. This climate zone spans the northeastern region of China, such as Beijing, Heilongjiang and Jilin provinces and has the greatest potential for both aboveground and belowground carbon sequestration compared with the other four climate zones. In addition to the snowy climate zones, the warm temperate and desert climate zones exhibit excellent potential for carbon sequestration through forest management; however, the plant species selected in these two regions may require resistance to waterlogging or drought on the basis of annual precipitation levels [58].

Conclusion

Researchers have been studying different pathways for limiting climate change over the past few decades and have reached the consensus that the most mature CO_2 removal method is to improve the use of land-based strategies. However, current efforts in the implementation of NCSs are not scaled to maximize carbon capture. Policies between 2009 and 2019 allayed only approximately 0.5% of the total emissions during the period. Delays in the implementation of modification policies may increase costs to society for both modification and adaptation, as they continue degrading the capacity of natural systems to moderate climate change and provide ecosystem services.

This study provides an important comparison of the carbon sequestration potential between active and passive forest management restoration strategies. A synthesis of the results of past studies revealed that forestation has greater potential for enhancing carbon sinks than doe's natural forest regrowth. In addition, this study aimed to optimize both aboveground and belowground carbon sequestration, considering the amount of SOC loss due to microbial respiration following forest management. The comparison of different forest management strategies provides a reference for future studies of land-based modification solutions. The results of this study provide a theoretical basis for future policy implementation and NCS establishment considering environmental variations, benefits and trade-offs. Overall, the northeastern region of China is identified as the most suitable region for forest management intervention.

Considerable scientific work is required in the future to further refine and reduce the uncertainty of identifying the most suitable forest management strategy in China. Our study prioritized area-weighted carbon sequestration potential as the main factor for comparing the effectiveness of different forest management strategies. However, the results of the comparison of these strategies may vary regionally if other factors, such as the benefits of providing ecosystem services, natural resource requirements and economic or environmental feasibility, are added to the evaluation. Additionally, the environmental factors that influence the SOC response following forest management must be assessed to refine the identification of the most suitable regions for forest management in China. As other environmental factors, such as altitude, soil depth and iSOC level, also influence the SOC response, considering only annual temperature and precipitation cannot provide a complete representation of the potential of different climate zones for increased SOC accumulation. Optimizing a region-specific forest management strategy is necessary to increase the effectiveness of carbon sequestration and avoid unintended trade-offs, as essential steps for China to meet the goal of becoming carbon neutral before 2060.

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