Hapres | Journal of Sustainability Research

sustainability.hapres.com

Article

Assessing Forestry Strategy for Addressing Climate Change and Its Challenges Toward Carbon Neutrality in China

Siqi Zhao [1,2], Chunho Yeom [2,*], Hanjiang Cai [1,*], Qiang Wang [2,3]

1 China National Bamboo Research Center, Chinese Academy of Forestry, Hangzhou 310012, China

2 International School of Urban Science, University of Seoul, Seoul 02504, Korea

3 Institute of Highland Forest Science, Chinese Academy of Forestry, Kunming 650233, China

* Correspondence: Chunho Yeom, Email: chunhoy7@uos.ac.kr; Hanjiang Cai, Email: estrellacai@sina.com.

ABSTRACT

Background: China's terrestrial ecosystem carbon sink, in which forests contribute the most, offsets 7%–15% of national anthropogenic emissions by approximately 80%. China's forestry strategy for addressing climate change has been receiving much attention concerning its role in climate change mitigation and in helping to achieve carbon neutrality.

Methods: China's forestry strategy for addressing climate change was assessed using qualitative data from document analysis and literature review; Challenges toward carbon neutrality were derived from in-depth interviews.

Results: A self-developed extension of relevant frameworks were employed to assess China's forestry strategy for addressing climate change in four aspects: increasing carbon sink, preventing carbon emission, storing harvested wood product carbon, and substituting forestry bioenergy carbon. Challenges and recommendations were presented from a multidimensional perspective using interviews with government officials, experts, and professors.

Conclusions: Environmentally, China need to emphasize science-based and large-scale greening, improve forest quality by precise tending, establish a more climate-resilient and adaptive forest ecosystem, and curb the spread of exotic forest pests through early warning in forestry strategy formulation to maintain and improve the forest carbon sinks and maximize their contribution to carbon neutrality. Socioeconomically, promoting forestry carbon education and knowledge, enhancing publicity and social awareness of wood and bamboo products via multiple platforms, and balancing the timber supply and demand flexibly without sacrificing the forestry economy's growth are essential for China. Technically, it is vital to improve the quality and stability of wood and bamboo products and extend their service life and carbon storage time, make a breakthrough in forest biomass thermochemical conversion and

Open Access

Received: 24 February 2023
Accepted: 25 September 2024
Published: 29 September 2024

multi-coupling technology, optimize forest carbon measurement and monitoring system, and carry out research on the critical technology of forest sink enhancement.

KEYWORDS: climate change; carbon neutrality; forestry strategy and policy; carbon emission; forest bioenergy

INTRODUCTION

Background

Since the industrial revolution, global development has relied heavily on overexploiting natural resources. With the excessive usage of fossil fuels, deforestation, and other land use changes, human activities have contributed enormous amounts of greenhouse gases (GHG), thus causing global climate change. However, CO_2 is not the only GHG that is driving global climate change. There are a number of others—methane, nitrous oxide, and trace gases such as the group of 'F-gases' which have contributed global warming. The IPCC has suggested the net-zero CO_2 emissions by 2050, a goal commonly known as "reaching carbon neutrality". The 2015 Paris Agreement urged the member parties to limit the global temperatures rise to less than 2 ℃ compared to pre-industrial levels and to achieve global carbon neutrality by 2050–2100. Carbon neutrality has been accepted worldwide since then [1]. Forests conserve biodiversity, control erosion, reduce flooding, store nutrients, regulate regional climates, offer recreational opportunities, and mitigate climate change by storing carbon. Indeed, the world's forests are estimated to absorb approximately two pentagrams of carbon annually, accounting for 30% of yearly human carbon emissions [2], roughly the same amount as oceans absorb [3].

As one of the largest CO_2 emitters, China significantly participates in global climate change actions. Policies and strategies are necessary to ensure decarbonization. Besides the energy, industry, construction, transportation, and other sectors, strategies, including expanding non-fossil fuels and increasing forest stock volume [4], have been applied to facilitate CO_2 reduction along with China's Five-Year Plans (FYP). In the 11th–13th FYP period (2006–2020), Nationally Appropriate Mitigation Actions (NAMAs) (2006–2020) has been taken to reduce the CO_2 emissions per unit of GDP by 40%–45% over 2005 by 2020. CO_2 emissions per unit of GDP were reduced by 48.4% over 2005 by 2020. Polices including Implementation Programme for the CO_2 Emission per Unit of GDP Control Target Assessment System in the 12th FYP Period (2011–2015), GHG Control in 12th FYP, GHG Control in 13th FYP, 2014–2015 Action Plan on Energy Conservation, Emission Reduction and Low-Carbon Development (2014–2015), National Plan on Climate Change (2014–2020), Developing non-fossil energy (2016–2020), Developing Natural Gas (2016–2020), Control over Coal Consumption (2016–2020), Developing Hydropower

(2016–2020), Developing Wind Power (2016–2020), Developing Solar Power (2016–2020), Developing Nuclear Power (2016–2020), Nationwide Energy Conservation Action (2016–2020), Energy Conservation in industry sector (2016–2020), and a series of related activities in energy, industry, construction, transportation and other sectors were adopted to complete the NAMAs.

Moreover, the Chinese government proposed the updated climate target in September 2020, achieving carbon neutrality by 2060 [5], in which the forestry sector plays an essential role as a negative emission reduction technology [6]. However, the conversion time from carbon peak to carbon neutrality is 50–70 years for the United States and the developed European countries, whereas it is only 30 years for China. From 2020 to 2060, China's forestry climate mitigation activities and other harmful emissions will contribute approximately 25% of overall emission reductions [4]. Given the realities of a high carbon-based energy consumption structure and annual emissions of over 10 billion tons of CO_2, achieving carbon neutrality should be accomplished through long-term development [7]. China's terrestrial ecosystem carbon sink, where forest contributes the most, is offsetting 7%–15% of national anthropogenic emissions [8] by approximately 80% [9].

According to the official information in China's National Communication on Climate Change and China's First Second and Third Biennial Update Report on Climate Change, in 1994, China's total GHG emissions (with LULUCF) were 3650 Mt CO_2 eq, net removal of LULUCF was 407 Mt CO_2 eq (11.15%); 7249 Mt CO_2 eq in total and 766 Mt CO_2 eq removal (10.57%) in 2005; 9551 Mt CO_2 eq in total and 993 Mt CO_2 eq removal (10.40%) in 2010; 11,320 Mt CO_2 eq in total and 576 Mt CO_2 eq removal (5.09%) in 2012; 11,186 Mt CO_2 eq in total and 1115 Mt CO_2 eq removal (9.97%) in 2014; 10,896 Mt CO_2 eq in total and 1340 Mt CO_2 eq removal (12.30%) in 2018. Therefore, the result of LULUCF removal percentage (5.09%~12.30%) provides further support for the growing importance on China's forestry sector in its climate governance framework, particularly in mitigation. In this sense, forestry strategy for addressing climate change has received much attention concerning its role in helping to achieve carbon neutrality.

Problem Statement

China's forest area, forest coverage, forest stocking, and forest carbon storage have improved significantly, with the forest product industry value increasing tremendously since China's reform and opening up [10]. However, how these changes relate to the corresponding forestry strategies for addressing climate change has not been fully understood from a systematic assessment—thematic analysis of increasing carbon sink, preventing carbon emission, storing harvested wood products carbon, and substituting forestry bioenergy carbon, respectively.

Moreover, China's new carbon neutrality target set in October 2020 provides challenges and opportunities for the forestry sector.

Therefore, by assessing the development progress thematically under China's corresponding forestry strategies and by analyzing the future challenges from a multidimensional perspective (environmental, socioeconomic, and technological), the underlying mechanism that considers interactions between diverse sectors to identify interconnected challenges and recommendations in implementing China's forestry strategies for addressing climate change and for helping to achieve the carbon neutrality goal can be figured out.

Research Questions

From a thematically systematic assessment, what is the development progress of China's forestry strategy for addressing climate change?

From a multidimensional perspective, what are future forestry strategy development challenges toward carbon neutrality in China?

Literature Review

Climate change and carbon neutrality

The carbon neutrality concept was initially proposed by a London-based company, Future Forests (later renamed Carbon Neutral UK), in 1997. The company offered carbon reduction services to families and individuals who bought certified carbon credits to offset their emissions. Because of its popularity, the carbon neutrality concept has been extended to counterbalance a country's or business's carbon emissions through afforestation, carbon sequestration, energy conservation, and environmental protection and to achieve relatively "zero net emissions" [1].

Simultaneously, many nations are pursuing carbon neutrality and other climate change initiatives. Thirty-two nations signed the Carbon Neutrality Coalition at the One Earth Summit in 2017 [11]. As of June 2022, 137 countries have pledged to achieve carbon neutrality [12]. Suriname and Bhutan have already achieved the goal of carbon neutrality. Denmark, France, Hungary, New Zealand, Sweden, and the United Kingdom have carbon-neutral targets in their laws. Canada, Chile, Fiji, South Korea, Spain, and the European Union have proposed carbon neutrality legislation. Meanwhile, Austria, China, Costa Rica, Finland, Germany, Iceland, Ireland, Japan, Norway, Portugal, Slovenia, South Africa, Switzerland, and the Marshall Islands have indicated achieving carbon neutrality in their policy papers [13].

There are two ways to achieve carbon neutrality: one is to reduce carbon emission, and the other is to increase carbon sequestration. Negative emission technologies, including leveraging forests and soil as carbon sinks, cannot solve the emission problem alone. Besides, it should also be acknowledged that it takes a long time for trees to grow, and the size of the carbon sink is limited. Carbon neutrality can be gradually achieved with emissions reduction measures taken proactively at the same time.

Forestry strategy and climate mitigation

Forests are distinctive among all feasible solutions for limiting GHG emissions because they can mitigate climate change while delivering environmental and social benefits, e.g., clean water, fresh air, habitat for wildlife, forest products, places for recreational activities, and other benefits. Climate mitigation in forestry strategy means increasing forest carbon sinks, reducing carbon emission by enhancing forest resources, thereby carbon sinks, extending and enhancing carbon storage in harvested wood products, and replacing carbon-intensive materials or products with forest biomass products.

The 2015 Paris Climate Agreement (UNFCCC 2015a) recognized the significance of forests in eliminating extra CO_2 from the atmosphere, highlighting the role of cutting emissions through forest protection and avoiding deforestation and forest degradation after 23 years of the climate treaty [14]. Table 1 summarized the process of forestry strategy at the global scale to better understand the role of forests in the global climate regime.

Table 1. Process of global forestry strategy under the climate regime.

Year	Agreements	Progress
1997	Kyoto Protocol	Quantitative emission reduction measures have been put forward for developed countries, one of which is “Afforestation, Reforestation, Sustainable Forest Management”.
2007	Bali Roadmap	Policy approaches and incentives for reducing emissions from deforestation and forest degradation (REDD) in developing countries have been approved in Bali Action Plan.
2009	Copenhagen Accord	The crucial role of reducing emission from deforestation and forest degradation to mobilize financial resources from developed countries emphasized encouraging developing countries to take action as soon as possible.
2010	Cancun Agreements	The Cancun meeting approved two forestry decisions. According to the Cancun accord, a cap on the total amount of carbon sinks should be set to offset emissions from industry and energy consumption. Those carbon sinks should be accounted for from related forest management activities that can be used.
2011	Durban Platform	Finance for forest carbon emission has proceeded. Efforts on Long-term Cooperative Action (LCA) of financing and Subsidiary Body for Scientific and Technological Advice (SBSTA) were made, which signaled the positive development of the REDD+ project.

Table 1. *Cont.*

Year	Agreements	Progress
2013	Warsaw Framework	Warsaw Framework was a significant move in making REDD+ (reduce emissions from deforestation and forest degradation, as well as the sustainable management of forests and the conservation and enhancement of forest carbon stocks in developing countries) into reality. Major issues including finance, transparency, safeguards, monitoring, verification, institutional arrangements, as well as addressing the drivers of deforestation were negotiated. Specific actions for sustainable management and increasing forest carbon storage were proposed to provide incentives.
2014	Lima, COP20	The forest and climate agenda were discussed in the REDD+ Partnership, SBSTA, the Subsidiary Body for Implementation, the voluntary Focal Points Annual meeting and the Ad Hoc Working Group on de Durban Platform for Enhanced Action (ADP) discussion.
2015	Paris Agreement	Paris Agreement reached set out the separate forest-related articles for forests and established a framework arrangement for the global joint response to climate change after 2020. In particular, a pre-assessment of progress towards the goals proposed by countries will be conducted starting in 2018: Forestry target in INDC.
2016	Marrakesh, COP22	Marrakesh action proclamation and Procedural issues arrangements for Paris Agreement.
2017	Bonn, COP23	Facilitating the climate action arrangement by the end of 2020.
2018	Katowice, COP24	Facilitating the implementation details of Paris Agreement.
2019	Madrid, COP25	Strengthen the implementation details of Paris Agreement.

Global carbon sink and carbon source

Carbon sink means any process, activity, or mechanism that removes GHG from the atmosphere, while carbon source means any process or activity that releases GHG into the atmosphere [15]. Harris et al. have integrated ground and Earth observation data to map annual forest-related GHG emissions and removals globally at a spatial resolution of 30 m from 2001–2019 [16]. The results showed that forests were a net carbon sink of −7.6 ± 49 Gt CO_2e/year worldwide, indicating a balance between total carbon removals (−15.6 ± 49 Gt CO_2e/year) and emissions from deforestation and other forest disturbances (8.1 ± 2.5 Gt CO_2e/year).

According to the Global Forest Resources Assessment (2020) by the Food and Agriculture Organization (FAO) [17], forest growing stock is used by many countries as the foundation for estimating biomass and carbon stocks. Forest biomass is the dry weight of living vegetation, an indicator of a forest's productivity and capacity to sequester and store carbon. From 1990–2020, the total growing stock declined slightly while increasing per unit area. The latter is genuine and particularly significant in East Asia and

Europe (excluding the Russian Federation). However, the global biomass stock decreased by about 8 Gt from 1990–2020, with Africa and South America witnessing the largest decreases due to the significant declines in the forest area.

Conversely, total biomass stock increases in Asia, Europe, and North America. The growing stock per unit area has increased in East Asia because China, Japan, and the Republic of Korea have undertaken major reforestation programs in recent decades, leading to substantial increases in growing stock. In contrast, the growth in Europe is most likely caused by improved forest management techniques that stimulate forest growth [17].

Forests can absorb vast amounts of CO_2 in the atmosphere and release O_2 by photosynthesis in the growth process [18], where carbon can be fixed in forest ecosystems. Previous researchers have found that forests can absorb 1.83 tons of CO_2 and release 1.62 tons of O_2 on average for every cubic meter of volume growth [19]. Furthermore, as the largest terrestrial carbon sink, forest ecosystems provide important ecosystem services, especially climate regulation via carbon sequestration [20]. Understanding the status and trends of various forest carbon pools is essential for recognizing the role of forests' global carbon cycle and forestry strategy in climate change mitigation.

Increasing carbon sink

Afforestation is a sub-category of forest expansion, referring to the establishment of forests on land that has not previously been forested [17]. It is a practical and optimal strategy for climate change mitigation due to its cost-effectiveness [21] and an essential negative-emission technology in many existing scenarios meeting the goal of 2 ℃ or 1.5 ℃ [22]. Reforestation refers to re-establishing forests where they were recently removed or destroyed (e.g., land severely affected by forest fire). It can restore carbon, oxygen, and nutrients' biogeochemical cycling [23], a crucial strategy for mitigating climate change and reducing biodiversity loss [24].

Improved forest management refers to activities that increase carbon stocks within forests and/or reduce GHG emissions from forestry-related activities compared to business-as-usual practices (UN-REDD). Intensive forest management (IFM) is frequently utilized to increase productivity and timber quality in the shortest time [25]. Extensive forest management (EFM), as an intermediate compromise strategy, is the practice in-between of forest conservation and IFM for carbon sequestration and soil carbon storage [26]. EFM is "the practice of forestry based on low operating and investment costs per acre" [27]. By applying long rotations and moderate harvesting intensities, EFM can increase carbon storage and deliver other economic and ecosystem services simultaneously [28].

Reducing carbon emissions

Deforestation and forest conversion (from forest lands to other land uses, e.g., agriculture, residential, and commercial development) result in significant carbon losses from live and dead biomass and organic soil matter, thus causing dramatic carbon emissions even if wood products are produced [29]. The Nature Conservancy, World Resource Institute, and other authors collaboratively estimate that halting deforestation, restoring forests, and improving forestry practices can offset 7 billion metric tons of CO_2 per year cost-effectively [30], equal to eliminating 1.5 billion cars [31].

As Harris et al. accounted, there are 8.1 ± 2.5 Gt CO_2e/year GHG emissions resulting from deforestation and forest disturbances, with CO_2 as the dominant component [16]. It reinforces the necessity and urgency to stop emissions from tropical deforestation. In tropical countries with high emissions from deforestation, beef production, soy, crops, and other agricultural production, oil palm plantations for industrial use are the dominant drivers of deforestation [32].

Global fires have broad effects on the global carbon cycle, including immediate direct carbon emissions to the atmosphere of nearly 2 Gt carbon per year [33] and indirect legacy carbon sinks of the places that have been burned in the past. The postfire lands that cannot be replaced by forest regeneration or soil carbon replenishment account for approximately 20% of the world's fire emissions [34], which are irreversible sources of CO_2 on the decadal to centennial time scales. Tropical deforestation, degradation, and peatland fires fall into this irreversible category [35], which has cascade consequences of increased tree mortality and further carbon loss.

Forest insect outbreaks and disease disturbances lead to tree mortality, reducing carbon sink capacity in many regions. Acting either alone or combined with other stressors, they can destroy and kill trees quickly [36]. When carbon emissions from wood decomposition in dead or injured trees outweigh living plants' carbon sequestration rates, forests convert from net carbon sinks into net carbon sources [37]. It leads to the emission of stored carbon and reduced forest carbon sequestration capacity.

Preventing carbon emission through wood substitution

Achieving the targets of the Paris Agreement requires innovation, efficiency improvements, and demand-side interventions. These interventions include product longevity improvements, increased product use, material efficiency, and material substitution, which can be motivated by a circular economy [38]. HWP from sustainably managed forests can be replenished continually, providing material supply and other ecological services [39]. Substituting wood for fossil fuel-intensive products avoids the emissions from the replaced products, while the carbon remains stored in HWP.

According to the China's Third Biennial Update Report on Climate Change, China's LULUCF absorbed 1340 Mt CO_2, among which, HWP absorbed 109 Mt CO_2 eq in 2018. As mentioned, forests can remove CO_2 and store it in their roots, stems, trunks, and leaves through photosynthesis. Furthermore, as forests mature, their growth slows down, while ecosystem carbon storage may increase due to carbon accumulation in other carbon pools [40]. Specifically, substituting lower embodied-carbon materials for higher embodied-carbon materials can be an optional forestry strategy for reducing industrial GHG emissions.

Building materials, especially concrete and steel, represent approximately 10% of worldwide emissions [41]. Globally, 4 Gt/year of cement and 1.8 Gt/year of steel [42,43] were produced. Due to this enormous production, few other materials are available to reduce their consumption sufficiently. However, timber-based products can be substituted for steel and concrete in low- and medium-rise buildings. Glued-and-laminated timber can bear the weight in high-rise buildings, and cross-laminated timber outperforms conventional plywood in strength and performance [44]. Moreover, timber frame constructions can substitute brick and concrete, fiberboards can substitute gypsum boards [45], wood fibers and straw can substitute insulation materials, etc. [46].

In addition to emitting far fewer GHGs in production, wood products store carbon for the structure's life. From a lifecycle perspective, wooden buildings typically outperform equivalent buildings made from concrete. Substituting wood for structural steel might be the most efficient way to use forests to mitigate GHG emissions [47].

Preventing carbon emission through biomass substitution

The transformation from a fossil fuel-dependent economy toward a circular bio-economy can bring the world closer to more sustainable production and consumption systems [48]. Phasing out fossil fuels spurs the growth of renewable energy. With the need for carbon emission reduction, the advocacy for technological advances, decreased production costs, and biomass as an energy source have been gaining much attention [49,50].

Accounting for 14% of global energy consumption in 2017, biomass might be the largest form of renewable energy, with 96% heat and 9% electrical production [51]. Forests and the forest industry account for over 85% of this biomass, supplying 77% biomass fuelwood, 8% charcoal, 7% recovered wood, 7% traditional forest product manufacturing residues, and 1% forest harvest residues [52]. There are several benefits from exploiting forest biomass as renewables, such as the ability to produce energy from small to high levels and the capability to support the grid with electricity in a more stable way than weather-influenced solar or wind power [51]. Biomass can be used as coal, natural gas, gasoline, diesel or fuel oil, and other fossil fuels, boosting rural economies and developing new industries of renewable fuels, chemicals, and other bio-based products [53]. According to previous research on conversion technologies, one dry ton of forest waste can be converted to 75–85 gallons of ethanol fuel or 550–650 kilowatt-hours of electricity [54].

However, FAO's latest statistics show that most bioenergy is used for cooking and heating in developing countries. Transitioning from a traditional to a more modern utility is essential to achieving sustainable development and a carbon-neutral society. Forest resource scarcity calls for social and technical innovation, leading to more efficient and circular uses of biomass resources [48]. Stronger coordination with the forestry sector is much needed to tap the synergies, unleash the potential, and avoid the negative impacts of developing forestry biomass energy, thus ensuring sustainability.

Research Significance

From the existing literature review, scholars have done detailed studies on the role of forestry activities in mitigating climate change. However, few thematically systematic reviews have assessed China's forestry strategy for addressing climate change since its first milestone policy was issued in 2009. Meanwhile, China's new carbon neutrality target set in October 2020 provides challenges and opportunities for the forestry sector, which requires more attention from a multidimensional perspective in this study, signifying environmental, socioeconomic, and technological perspectives.

Under China's current conditions, a qualitative theoretical study of the progress and challenges on the way to carbon neutrality can enrich research related to this topic, assist in establishing green, low-carbon economic development with Chinese characteristics, and provide recommendations for dealing with climate change.

Therefore, this research contributes to assessing the underlying mechanism of China's forestry strategy for addressing climate change, a mechanism for mitigation actions that correspond to national circumstances, to strengthen the sustainable and effective implementation of China's forestry strategy toward carbon neutrality by 2060.

MATERIALS AND METHODS

Data Source

Source 1: Government documents and reports

- China's four Five-Year Plans, from the 10th (2001–2005) to the 14th (2020–2025) periods.
- Six national climate change documents: (1) China's National Climate Change Program issued in 2007, China's first climate change policy initiative; (2) China's Nationally Appropriate Mitigation Actions issued in 2009; (3) China's Intended Nationally Determined Contributions (INDC) issued in 2015; (4) China's Updated Nationally Determined

Contributions (NDC) issued in 2020; (5) Responding to Climate Change: China's Policies and Actions issues in 2021; (6) China's Mid-Century Long-term Low Greenhouse Gas Emission Development Strategy issued in 2021.

- Ten corresponding documents in the forestry sector: China's Forestry Action Plan for Addressing Climate Change issued in 2009; Key Action for Addressing Climate Change in Forestry in the 12th Five-Year Plan Period and the 13th Five-Year Plan Period; Seven White Papers on China's Forestry Policies and Actions for Addressing Climate Change issued annually from 2014 to 2020.
- Two national carbon peaking and carbon neutrality policies: (1) Working guidance for carbon dioxide peaking and carbon neutrality in a complete and faithful implementation of the new development philosophy issued in 2021; (2) The action plan for carbon dioxide peaking before 2030.

Source 2: National official interview content

China Green Times, a national newspaper of the National Forestry and Grassland Administration (NFGA), has launched an exclusive series of the interview in March 2022, inviting experts and scholars from China's forestry and grass academia to interpret the role of forests as a reservoir, as a money bank, as grain reserves, and as a carbon pool [55–58].

Source 3: In-depth interview

- Selection of interviewees

This paper aims to find forestry development policies to strengthen the sustainable and effective implementation of China's forestry strategy toward carbon neutrality. Therefore, the main interview targets are civil servants, professors, researchers, and experts directly involved in forestry development policies. They are in key positions in forestry development and have unique experience and insight into issues such as climate change mitigation and its relationship with carbon neutrality. The specific list of interviewees is displayed in Table 2.

Table 2. A specific list of interviewees.

No.	Name	Occupation
1	Interviewee 1, PhD	Member of China Carbon Neutrality Forum Executive Deputy Director, State Forest Administration
2	Interviewee 2, Prof.	Director of the Carbon Neutrality Research Center of Nanjing Forestry University
3	Interviewee 3, PhD	Professor at the College of Forestry, Nanjing Forestry University, Doctor of Ecology
4	Interviewee 4, PhD	Chinese Academy of Forestry, Forestry Research Institute. Editor-in-Chief of White Paper of Forestry Strategy for Addressing Climate Change
5	Interviewee 5, Head of Office	China Forestry Industry Association

- Questionnaire design

The interviews were divided into five themes with a total of 11 questions. The questionnaire is attached in the Supplementary File.

- Organization of interviews

The interviewees were located in China, and a questionnaire was sent to them in advance and conducted at their convenience. Communication was in Chinese throughout the interviews, and the entire content was documented with consent. After the interviews were completed, the content was translated into English.

ASSESSING THE FORESTRY STRATEGY IN CHINA

During the past 40 years, China's forest carbon sink capacity has been continuously increasing. According to statistics from the National Forest Inventory (NFIs), Wang et al. estimated the full-scale carbon sinks in China's forest ecosystems, which are 175 million t/a (2nd: 1977–1981), 199 million t/a (3rd: 1984–1988), 200 million t/a (4th: 1989–1993), 264 million t/a (5th: 1994–1998), 319 million t/a (6th: 1999–2003), 359 million t/a (7th: 2004–2008), 403 million t/a (8th: 2009–2013), and 434 million t/a (9th: 2014–2018) [59].

Major Policy Changes Under the International Framework

Foundation of changes

In 1990, the United Nations General Assembly launched the global climate governance negotiations. In February this year, the Chinese government established the National Coordination Committee on Climate Change. After the UN Conference on Environment and Development in 1992, the Chinese government issued "China's Agenda 21: White Paper on China's Population, Environment and Development in the 21st Century", which ratified the UNFCCC in 1993.

With UNFCCC entering into force in 1994 and adopting the Kyoto Protocol in December 1997, the Chinese government signed the Kyoto Protocol in May 1998, the 37th signatory. In 1998, the Climate Change Office of the State Forestry Administration's Afforestation and Greening Department was set up. In 2003, the Forest Sink Management Leading Group was established to guide the management of forest sinks. In October 2005, China issued the "Measures for the Operation and Management of Clean Development Mechanism Projects".

Turning point of changes

In 2007, the Chinese government established the Leading Group on Climate Change and Energy Conservation and Emission Reduction and issued China's National Climate Change Program (2005–2010). The forestry sector has been included in this milestone Program, with the State Forestry Administration (SFA) designated as one of the seven deputy directors of the Leading Group. For over two years, starting from July 2007, the SFA formulated the “Forestry Action Plan to Address Climate Change (2009–2050)”, which specifies the basic principles, visions and missions, and main actions to mitigate and adapt to climate change through forestry development.

In 2008, the Climate Change Department of the National Development and Reform Commission was established. In September of the same year, China officially launched The Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet), a non-profit international organization dedicated to advancing sustainable forest management and rehabilitation in the Asia-Pacific region.

Milestones leading to the chain of changes

In 2009, with the launch of the Nationally Appropriate Mitigation Actions (2005–2020), which specifies the target of increasing forested area by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020, the milestone policy-Forestry Action Plan for Addressing Climate Change (2009–2020) has been issued.

In 2011, the State Forestry Administration released the National Layout Plan on Afforestation (2011–2020). In 2014, the “National Climate Change Plan (2014–2020)” was issued. In 2015, China announced its Nationally Determined Contribution; In September 2016, China joined the Paris Agreement, the 23rd party of ratification. In 2016, the State Forestry Administration issued the National Forest Management Plan (2016–2050).

In 2018, China adjusted the functions of relevant departments. The newly formed Ministry of Ecology and Environment was designated to take responsibility for climate change to strengthen the synergy between addressing climate change and ecological and environmental protection.

In 2020, President Xi Jinping announced China’s new Nationally Determined Contribution. In 2021, China announced the new Leading Small Group on carbon peak and neutrality, followed by The Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy (2021–2060) and The Action Plan for Carbon Dioxide Peaking before 2030.

In 2022, the NFGA set up a special team for addressing climate change and was preparing to establish a research institute on carbon sinks.

Forestry Development Under China’s Climate Framework

The Chinese government attaches great importance to forestry in response to climate change and has taken a series of policies, making four precise strategic arrangements in recent years.

First, the role is clarified. In 2009, the Central Forestry Work Conference clarified that “in response to climate change, forestry has its special and unique role” and emphasized that “the development of forestry should be a strategic choice in addressing climate change”.

Second, the authoritative function is distinct. The State Forestry Administration was explicitly assigned to the responsibilities and obligations of forestry in China's climate change actions. This commission was officially from the General Office of the State Council in 2008.

Third, the objective is explicit. At the United Nations Climate Change Conference in 2009, President Hu Jintao declared that China would increase forest carbon trading, raise forest cover by 40 million hectares by 2020, and achieve 1.3 billion cubic meters of stock volume from the 2005 level. The Chinese government has committed to implementing the 2020 GHG Emissions Action Plan, which includes the "double increase" target for future forestry development.

Fourth, the mission is straightforward. Forestry was highlighted as one of the critical sectors in the State Council's "National Action Plan to Address Climate Change", published in 2007. A working schedule for reducing GHG emissions during the 12th Five-Year Plan was approved by the State Council in 2011, calling for a 12.5 million hectare increase in forest coverage which means a 21.66% increase, a 600 million cubic meter growth in forest stock volume, and an increase in forest carbon sinks. Forest area and forest growth volume are two essential indicators to evaluate the performance of related officials under the 12th National Five-Year Plan. Forestry has become one of the core sectors of the national strategy to promote sustainable socioeconomic development and combat climate change.

In 2003, the Forest Sink Management Leading Group was established to guide the management of forest sinks. In 2007, the government established the Leading Group on Climate Change and Energy Conservation and Emission Reduction. In 2011, the membership of the Leading Group was expanded to strengthen its functional role. In 2009, the State Forestry Administration formulated and released the "Forestry Action Plan to Address Climate Change", which clarified the guidelines, objectives, critical areas, and major actions for forestry to address climate change. In 2011, the government also issued a significant action plan to address climate change in forestry during the 12th Five-Year Plan period. In 2016, the State Forestry Administration (SFA) released the "13th Five-Year Plan", significant actions to address climate change in forestry. The State Forestry Administration released the 12th (2010–2015), 13th (2016–2020), and 14th (2021–2025) five-year plans for forestry development in 2011, 2016, and 2021, respectively.

The national legislation and policies regarding forestry strategy for addressing climate change in China are summarized in Table 3.

Table 3. China's forestry-related policies and strategies (Revision year is marked by "r", e.g., 2014r).

Year	Time frame	Legislation, strategy, and policy
Legislation		
1989, 2014r	1989	Environment Protection Law
1985, 2019r	1985	Forest Law Strategy and Policy
2001	2001–2005	10th Five-Year Plan: Increase forest coverage to 18.2% by 2005
2006	2006–2010	11th Five-Year Plan: Increase forest coverage to 20% by 2010
2007	2005–2010	China's National Climate Change Program: Increase forest coverage to 20% by 2010
2009	2005–2020	Nationally Appropriate Mitigation Actions: Increase the forested area by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020
2009	2009–2050	Forestry Action Plan for Addressing Climate Change
2011	2011–2015	12th Five-Year Plan: Increase forest coverage to 21.66% and forest stock volume to 14.3 billion cubic meters by 2015
2011	2011–2015	Work Scheme on Greenhouse Gas Emission Control in the 12th Five-Year Plan Period
2011	2011–2015	Key Action for Addressing Climate Change in Forestry in the 12th Five-Year Plan Period
2011	2011–2020	National Layout Plan on Afforestation
2011	2011–2020	National Plan for Forestry Biomass Development
2014	2014–2020	National Climate Change Plan
2015	2005–2030	Intended Nationally Determined Contributions: Increase forest stock volume by 4.5 billion cubic meters from 2005 levels by 2030
2016	2016–2020	Key Action for Addressing Climate Change in Forestry in the 13th Five-Year Plan Period
2016	2016–2050	National Forest Management Plan
2016	2016–2020	Forest Quality Precision Improvement Project in the 13th Five-Year Plan Period
2016	2016–2020	Action Plan for China's Forestry Sector in Adaption to the Climate Change
2017	2017–2030	China's National Plan on the Implementation of the 2030 Agenda for Sustainable Development
2018	2018–2025	National Forest City Development Plan
2018	2018–2035	National Reserve Forests Construction Plan
2019	2019–2025	Promoting the High-Quality Development of the Seedlings
2021	2021–2025	14th Five-Year Plan and Long-Range Objectives through the Year 2035: Increase forest coverage to 24.1% by 2025

Table 3. *Cont.*

Year	Time frame	Legislation, strategy, and policy
Legislation		
2021	2021–2060	The Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy
2021	2021–2030	The Action Plan for Carbon Dioxide Peaking before 2030
2021	2021–2060	China's achievements, New Goals, and New Measures for Nationally Determined Contributions (updated NDCs)
2021	2021–2060	China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS)
2021	2021	Guideline for Scientific Afforestation
2021	2021–2025	14th Five-Year Plan on the Protection and Development of Forests and Grasslands: Increase forest coverage rate to 24.1 percent and its grassland vegetation coverage to 57% by 2025
2021	2021–2030	Implementation Plan on Consolidating and Enhancing the Ecosystem's Carbon Sequestration Effect (2021–2030)
2021	2021	Guideline for Implementing Forest Chief Scheme
2022	2021–2025	Forestry and Grassland Industry Development Plan (2021–2025)
2023	2023–2025	Three-Year Action Plan for the Revitalization of the Forestry and Grassland Seed Industry (2023–2025)
2023	2023–2025	Three-year Plan for Promoting Bamboo as an Eco-friendly Substitute for Plastic (2023–2025)

Under the guidance of China's national forestry plans and driven by the targets in these FYPs, China's forest coverage has been increasing according to the latest NFI, which has completed the goals and targets set before. Table 4 summaries the changes in detail.

Table 4. China's forest coverage of previous NFIs.

Source	1st NFI	2nd NFI	3rd NFI	4th NFI	5th NFI	6th NFI	7th NFI	8th NFI	9th NFI
Time Frame	1973–1976	1977–1981	1984–1988	1989–1993	1994–1998	1999–2003	2004–2008	2009–2013	2014–2018
Forest Coverage	12.7%	12.00%	12.98%	13.92%	16.55%	18.21%	20.36%	21.63%	22.96%

Increasing Forest Carbon Sink Capacity

Enhancing afforestation and greening efforts

Two factors are primarily attributed to establishing China's terrestrial carbon sink. First, the rise in atmospheric CO_2 has pushed China's naturally less disturbed and mature ecosystems into a state of disequilibrium by increasing carbon gain more than carbon release, similar to the global land carbon-sink pattern. Second, the widespread ecological restoration initiatives, such as national land greening, afforestation, and natural forest conservation, generated vast areas of secondary forests at an early successional stage with a young age, delivering a powerful carbon sink [8].

Afforestation and greening efforts contribute to increasing forest areas and forest sinks reserves. NFGA issued the 12th five-year plan for forestry development and the national blueprint for afforestation and greening (2011–2020), which set the afforestation and greening tasks for each region and department, respectively. These served as the foundation for an increase of 40 million hectares of forests by 2020 and an increase in forest sinks from the 2005 figures.

Improving forest cultivation and management

Forest quality, volume, and sink capacity can be improved through better cultivation and management activities. NFGA set up a leading forest cultivation and operation group and offered subsidies from central finance. In 2011, central finance offered over 5 billion RMB in subsidies across the country, which supported a 1.3 billion cubic meter increase in forest volume and forest sink capacity by 2020 from the 2005 figures.

Practices and current status of china's forest

Behind the continuous increase of forest carbon sinks are the continuous large-scale ecological restoration, land greening, and forest quality improvement actions, especially since the reform and opening up. The forest area and volume have maintained "double growth" for 30 consecutive years, achieving the world's most significant increase in forest resources.

At present, China's forest coverage is 23.04%, the total carbon storage of forest vegetation has reached 9.186 billion tons of carbon, the annual water conservation volume is 628.950 billion cubic meters, the annual soil retention volume is 8.748 billion tons, and the annual dust retention volume is 6.158 billion tons; The annual absorption of air pollutants is 40 million tons, and the annual oxygen release is 1.029 billion tons [60]. China's forests have delivered enormous ecosystem services and embodied a tremendous ecological value.

The formation and role of forest carbon pools are closely related to national strategies such as ecological protection, environmental governance, and rural revitalization. According to the "Ninth National Forest Inventories Report", China now has 82.74 million hectares of state-owned forests, 38.74 million hectares of collective forests, and 96.73 million hectares of individual forests.

Social governance provides an essential foundation for policy implementation. Developing multi-beneficial afforestation, reforestation, and forest quality improvement carbon sink projects can strengthen biodiversity conservation, enhance the ability of nature reserves and surrounding communities to adapt to climate change, boost local economic development, and promote rural revitalization. It is of great significance to fulfill the carbon neutrality goal vision that China has promised to the world.

Preventing Forestry Carbon Emissions

Natural forest preservation

China has been carrying out the comprehensive protection of natural forest resources. The General Office of the Central Committee of the Communist Party of China and the General Office of the State Council have issued the "Plan for the Protection and Restoration of Natural Forests", which determines visions and missions, effective regulations, supporting policies, and safeguard measures by 2020, by 2035, and by the middle of this century, respectively. In 2019, the central government invested 43.4 billion yuan in natural forest protection, and natural forests were able to recover fully [61]. The old-growth ancient and rare trees can be rescued with related activities. Such conservation measures ensure that natural forests are well-protected.

Improving forest harvesting practices

China has implemented "Measures for the Administration of Forest Harvesting and Revegetation" to strengthen the protection and utilization of forest land, timber logging, and national forest management for public benefit. Forest land use for construction projects such as wind farms is further standardized, and the full use of forest land and timber is effectively controlled. Forests located in important and fragile ecological zones are ensured to be protected. Forest resources are monitored frequently using high-resolution remote sensing technologies, on-site verification, etc. Thus, problems can be identified promptly, and violations of laws and regulations can be investigated and dealt with following the law.

Forest fire and pest control

Strictly preventing forest fires and reducing resource loss is one of the strategies for preventing emissions from forest disasters. This strategy follows the principle of "prevention first and extinguishes the fire in an orderly manner that follows the law of science". Since 2012, the national forest fire loss rate has been controlled below 1‰. On average, there are 3150 forest fires per year, and the damaged forest area of 13,000 hectares, about 1/3 and 1/10 compared with the last decade, has dramatically reduced carbon emissions. Experts estimate that China can reduce carbon emissions by 50 million tons annually through forest fire prevention and control [62].

The "National Mid- and Long-term Development Plan for Forest Fire Prevention (2009–2015)" was implemented to strengthen the forest fire prevention, rescue, and security systems. “Regulations on Forest Fire Prevention” was carried out to enhance the legal system and forest fire management per the law. National Forestry Pest Control and Construction Plan (2011–2020) aims to strengthen the construction of the control and service guarantee systems regarding forest pests and diseases quarantine, disaster prevention, monitoring and early warning, and emergency prevention.

The above regulations also emphasized the prevention, control, and management of Bursaphelenchus xylophilus diseases, fall webworms, and other major forest pests. Actions were taken in pollution-free control measures for forest diseases and insects mainly based on biological control. Special rectification actions were carried out for forestry law enforcement under the law to curb illegal logging and strengthen forest fire, disease, and insect pest control to reduce forestry carbon emissions. As mentioned above, strengthening ecological protection and forest disaster control can reduce forest greenhouse gas emissions. NFGA strengthened forest land protection and forest felling management, increased forest fire and forest insect control, and lowered forest carbon emissions.

Carbon Storage in Harvested Wood Products

China’s fast-increasing construction market ranks first in the world, and policies support using green building materials. It offers market possibilities for producers of wood products and softwood-sawn wood at home and abroad [48]. Experts estimate that from 1961 to 2004, carbon storage in China’s wood products is about 1.2 billion to 1.8 billion tons of carbon dioxide equivalent, an essential contribution of forestry to climate mitigation (China Green Carbon Foundation). Furthermore, China has issued “Key Points of Forest Industry” to promote the circular economy in the forestry sector.

According to the Chinese Academy of Forestry, technological breakthroughs have enabled high-performance wood and bamboo recombination engineering materials. Wood and bamboo fiber-based steel materials are characterized by their “specific strength”, which means five times that of ordinary carbon structural steel. Energy consumption for production is 1/30 times less than steel and 1/5 less than cement, while the thermal insulation effect is 10 times higher than that of concrete. They emit much less while storing much more carbon, thus contributing to carbon neutrality.

Carbon Substitution in Forest Bioenergy

China is the most prominent global producer and consumer of concrete, steel, coal, paper, and oil-based products such as polyester fiber and plastic. The transition from a fossil fuel economy to a more circular and less carbon-intensive economy is necessary for China to achieve carbon neutrality [48]. Technologies, products, and policies are needed to support these objectives.

In 2013, China issued the National Forestry Biomass Energy Development Plan (2011–2020). Each year China produces over 900 million tons of agricultural and forestry biomass, which can generate power equal to nearly 400 million tons of coal. The number is even more significant when adding organic waste from urban and rural areas. However, only around 90 million tons of agricultural and forestry biomass is used for power generation annually. Moreover, according to the latest data from the Office of the National Greening Committee (2017), the total biomass in China exceeds 18 billion tons, possessing massive potential for developing forest biomass energy. Three major forest biomass energy resources are available: First, xylem fiber materials, including firewood, shrubs and waste gas, wastewater, and waste residue from forestry industry production, which add up to 350 million tons. Second, woody oil plants, where there are more than 150 native plants with their seeds' oil content exceeding 40%. Among them are major energy plant species such as *Vernicia fordii* (Hemsl.) *Airy Shaw*, *Swida wilsoniana* (Wanger.), *Sojak*, and *Pistacia chinensis Bunge*, which add up to more than 1 million hectares. With over 1 million tons of fruits produced from major woody oil plants, 400,000 tons of biodiesel can be obtained if fully processed and utilized. Third, woody starch plants include oak fruits, vegetable chestnuts, fern roots, plantains, etc. Among them, oak species covering 16.1 million hectares, with 24.15 million tons of fruit production per year and 6 million tons of fuel ethanol, can be obtained if fully processed and utilized.

These rich forestry biomass resources can provide material for the sustainable development of forestry bioenergy and are used to a great extent to alleviate the national energy crisis, adjust and optimize the energy structure, achieve a sustainable supply of energy, and provide a robust resource guarantee. These abundant forest biomass resources can not only provide a good foundation as raw material for the sustainable development of forest bioenergy but also serve as a powerful safeguard for alleviating the national energy crisis, adjusting and optimizing the energy structure, and realizing sustainable energy supply if the huge potential was fully tapped.

INTERVIEW ANALYSIS AND DISCUSSION

Interview Results

Regarding the relationship between the forestry strategy for addressing climate change and carbon neutrality

Forestry is a critical sector in carbon neutrality policies, almost for all the committed countries, as IPCC has endorsed. China's current carbon neutrality policy framework explicitly recognizes the significance of the forestry sector. Regardless of how efforts are made to reduce industrial emissions, basic human needs will eventually emit a certain amount of carbon.

To achieve the transition from “near-zero” to “net-zero” emissions, the ability to fix CO_2 within the forestry sector may be the easiest and fastest, with minimum maintenance cost (Interviewee 2). Moreover, forestry carbon sinks consume zero electricity compared to other carbon capture and sequestration technologies.

However, the whole society does not pay enough attention to the contribution and potential of forestry in climate mitigation and carbon neutrality endeavor. Additionally, the statistical accounting methods lack uniform standards. As a result, the existing academic literature differed in their findings, with a wide range from 5% to 45% of how much China’s forest ecosystem can offset annual anthropogenic emissions. Therefore, carbon sink measuring, accounting, and monitoring systems should be improved. Based on the IPCC Guidelines that provide a technically sound methodological system for measuring national GHG inventories for afforestation and forest management-related projects, a regional carbon sink accounting and assessment model should be built (Interviewee 2), thus realizing accurate measurements.

As for the strategies with more challenges, the carbon sink finance and trading policies need further improvement, and the forest carbon market is relatively immature (Interviewee 4). Forest carbon trading has many monitoring and auditing procedures, and the transaction cost is high. These all make it more difficult for many forest carbon sink products to enter the market with real value, which demotivates forest carbon management entities and stakeholders.

Regarding increasing forest carbon sink capacity

According to the complete synthesis result of China’s Ninth National Forest Inventory, Forest and Grass Carbon Accounting and Monitoring, National Greenhouse Gas Inventory, and FAO, China’s forest ecosystem carbon storage exceeds 48.5 billion tons, ranking 5th after Russia, Brazil, Canada, and the United States. In the past decades, the net sink of CO_2 by China’s forest, grass, and land use changes has exceeded 1.1 billion tons, surpassing the United States, Russia, the European Union, and other countries and regions to ranking first, offsetting China’s 9% anthropogenic emissions, of which forests contribute 83% (Interviewee 1).

However, problems such as poor quality of forest resources, single species structure in plantations, uneven density, and low utilization rate of forest land are still prominent, despite China’s forests having maintained the “double growth” trend in forest area and stock volume (Interviewee 1). China’s forest stock volume is 94.83 cubic meters per hectare, only 72.4% of the world’s average, half of Brazil, and less than one-third of Germany. In particular, the artificial plantations, which account for 36% of China’s total forest area, are mostly dominated by a single tree species. In contrast, the natural forests, which account for nearly two-thirds of China's total forest area, are mostly secondary forests. Due to long-term over-harvesting, China's forests generally suffer from insufficient target tree species and poor structural stability. As a result, the multiple benefits of forest ecosystems, especially the carbon sink function, are difficult to exploit effectively.

China's forest has relatively poor stand structure, middle-aged and young forests with low-quality forests account for a large proportion, and deforestation sometimes may occur. Moreover, Interviewee 4 also believes that strategies in expanding the forest area, improving the forest quality, and strengthening the protection of the forested land possess more potential than other strategies. Following such approaches can significantly improve the forest carbon sink capacity, thereby accelerating the carbon neutrality target.

Therefore, in addition to expanding the area of newly planted forests by protecting existing forests, transforming forest plantations, and restoring degraded forests, those young and half-mature forests should play an essential role in the future. The young and half-mature forests, accounting for 60.94% of the total forest area, with their rapid growth and improved forest quality, have a higher rate of carbon sequestration and a greater potential for increasing carbon sinks compared with mature forests.

Furthermore, adjustments in forest structure can cause fundamental changes in the entire forest ecosystem, which can not only substantially increase carbon sinks, but also help to improve biodiversity, and other non-carbon benefits from forests, thus obtaining "high-quality ecological carbon sinks" and ensuring forests can deliver multiple benefits for the whole society. Through scientific forest tending, the tree species structure of forest stands is adjusted and optimized. Significantly, plantation forests dominated by coniferous trees can be adjusted into forests dominated by broad-leaved trees (Interviewee 1).

High carbon sink forest genetics and breeding technology should be developed, economic and applicable forest management technology that increases carbon sink and avoids emission should be advanced, and forest carbon sinks' accurate measurement technology should focus on reducing operational cost and minimizing the technological threshold (Interviewee 2).

The biggest challenge in increasing forest carbon sink, as argued by Interviewee 3, aims to incorporate the protection and conservation of forest soil carbon pools into the overall management of forest stands and to focus on maintaining the stability of soil carbon pools, which account for about half of the carbon storage in forest ecosystems. Such maintenance ensures sustainable operations in the forest carbon sequestration and accumulation process. One should develop technologies for afforestation on challenging lands in ecologically vulnerable regions (Interviewee 4).

Regarding preventing forestry carbon emission

Currently, the most significant challenges to preventing carbon emissions from China's forestry sector are further strengthening insect and disease control and reducing the ecological risks of monoculture brought by single tree species in certain regions, especially in *Pinus Massoniana* Lamb forests (Interviewee 4). Solving these problems requires a coordinated manner when managing the forest structure and following the industrial management approach in the agricultural sector (Interviewee 3), thus establishing a mechanism for maintaining forest biodiversity at the stand scale.

Rapid urbanization and infrastructure construction are transforming land use, calling for the strengthened protection of forests. Clear-cutting should be reduced, and continuous cover forestry techniques such as selective cutting and shelterwood cutting should be enhanced. Innovative afforestation techniques should be adopted, such as afforestation by transforming plant residues, which reduces harvesting residue and clean-up intensity, thus saving resources, labor, and energy. Technology and demonstration research on biological control should be carried out (Interviewee 4).

Regarding carbon storage in harvested wood products

Currently, HWP is not sufficiently well-utilized in China's construction sector. Bamboo and wood structure buildings should be encouraged, using various technologies to improve the stability of materials (Interviewee 2). By increasing the share of wood and bamboo products in commercial and civil construction and infrastructure, improving the recycling mechanism of forest products, developing energy-saving and emission-reduction technologies for the wood and bamboo industry, and extending the life cycle, the long-term carbon storage in more stable bamboo and wood products can be realized, with more carbon-intensive materials substituted.

Another significant aspect of forest product substitution lies in the bamboo forest (Interviewee 1). FAO says the total bamboo area worldwide has reached 35 million hectares [17]. China, known as the "kingdom of bamboo", with its total area of 6.4116 million hectare bamboo forests, is one of the countries with the wealthiest and most widely distributed bamboo resources in the world and has a long history of using bamboo resources.

Bamboos are distinct plants with a wide range of values and use.

First is timber substitution and resource conservation value due to bamboo's unique bio-ecological characteristics, such as rapid shoot growth rate and continuous, subsequent harvests once reaching maturity. As an excellent renewable biological material, 1.8 billion bamboo poles can be harvested annually, equivalent to more than 200,000 m^3 of timber.

The second is economic value for farmers' income. Bamboo is a versatile and edible plant that can be used in many ways. There are more than 10,000 bamboo products, including clothing, food, housing, transportation, and other daily products. Bamboo products are environmentally friendly and can be used in various fields such as construction, bridges, furniture, automobiles, durable household goods, bamboo winding utility tunnels for industrial use, and other daily necessities, such as disposable tableware like knives, forks and spoons, straws, cups, and plates. More importantly, almost every part of bamboo can be used, leaving zero waste.

Third is ecological value for the environment. Bamboo forests have many environmental benefits because they function as carbon sinks, produce oxygen, control soil erosion, provide organic matter, regulate water levels in watersheds, conserve biodiversity, beautify the landscape, and contribute to the purification and purification regulation of the environment.

Fourth is social value for employment. The bamboo industry is labor-intensive with a long industry chain, providing many labor force jobs, especially in rural societies. China has more than 45 million people engaged in bamboo forest management cultivation and the bamboo product processing industry. In addition, China's traditional bamboo culture has been rooted for a long time. Moreover, bamboo is a symbol of virtue reflecting people's souls and emotions throughout history, which can continuously enhance public awareness of ecological civilization and environmental protection.

Together, bamboo's various values provide essential insights into forestry strategies. According to NFGA, China's bamboo forests can reduce 197 million tons of carbon emission and absorb 105 million tons of carbon, adding up to 302 million tons of total carbon reduction and carbon sequestration per year. If 600 million tons of bamboo were used annually to replace PVC products worldwide, it is estimated that 4 billion tons of CO_2 emissions would be reduced.

In recent years, the sales of bamboo tableware, bamboo knives, forks and spoons, bamboo straws, bamboo keyboards and mice, and other daily necessities made from bamboo are proliferating, and the export volume is increasing yearly. However, plastic-based goods still take a much higher market share due to insufficient recognition of bamboo products. Experts in this field believe that the high cost is one of the key factors restricting the more comprehensive replacement of plastic products by bamboo products.

Therefore, encouraging enterprises and the public to use more bamboo products such as bamboo chopsticks and bamboo furniture and supporting bamboo instead of plastic will not only increase farmers' income but also reduce carbon emissions, thus contributing to the 2060 carbon neutrality goal for China and the entire earth (Interviewee 1).

Regarding increasing carbon substitution in forest bioenergy

Energy forests, in similar circumstances to the forests for carbon sequestration projects, have relatively less coverage in China. In addition, forest bioenergy accounts for a much smaller proportion of clean energy, with a much higher price than fossil fuels.

There is no doubt about the advantages of biomass energy, but improving the energy conversion efficiency of biomass energy while reducing the negative impact on the environment is a bottleneck calling for technical solutions. On top of that, the environmental pollution caused by the combustion process is a constraint that inhibits the widespread promotion of biomass energy.

Regarding the overall management of forestry carbon

First, the stand-scale carbon sink measurement is labor-intensive with low efficiency. There is considerable uncertainty in estimating regional-scale remote sensing, and there is no unanimous foundation model and no suitable carbon density measurement technique. Future forestry carbon sink measurement should be based on automatic integrated air-space-ground monitoring.

Second, regarding the strategies with more challenges, the carbon sink finance and trading policies need further improvement, and the forest carbon market is relatively immature (interviewee 4). Forest carbon trading has many monitoring and auditing procedures, and the transaction cost is high. These all make it more difficult for many forest carbon products to enter the market, demotivating the forest carbon management entity and stakeholders.

Third, regarding the direction of future forestry development, due to the unclear theoretical and practical timing of the establishment of the China Certified Emission Reduction (CCER) market system, China's forestry for addressing climate change should focus more on the model and measurement construction at the regional level, technology improvement on rapid carbon sink capacity evaluation, and establishment of a value-realization mechanism for ecological products at the local level (Interviewee 3). Carbon neutrality does not mean carbon trading as an economic behavior. Future forestry strategies for addressing climate change should comprehensively preserve and increase the value of ecological products. This is the primary path of China's forestry development under ecological civilization construction.

Finally, one of the biggest challenges for future forestry development is to change the mindset from simply focusing on forest stock volume management to biomass accumulation in the forest ecosystem as soon as possible at the local level. Such a changing mindset can comprehensively improve the forest's carbon sink capacity (Interviewee 3).

After completing the interviews, a multidimensional analysis from the environmental, socioeconomic, and technical perspectives can be carried out, respectively. Suggestions can be derived for strengthening the sustainable and effective implementation of China's forestry strategy toward carbon neutrality by 2060.

Analysis from the Environmental Perspective

Regarding forest quality, problems are reflected in forests' poor quality and productivity, especially plantations, although China's forest area has expanded. China's forest stock volume is 94.83 cubic meters per hectare, 72.4% of the world average of 131, and even only 59.30 in China's plantations. China has prioritized afforestation and reforestation for an extended period without paying proper attention to silviculture management. As a result, young and half-mature forests account for up to 65% of China's total forest area. Stocking levels in both natural forests and plantations are relatively low yet increasing.

The poor quality of forest stands has brought out other ecological risks, such as monoculture, especially in *Pinus Massoniana* Lamb forests (Interviewee 4). Even worse, monoculture plantations are at greater risk of pest outbreaks than natural forests, which harms the prevention of carbon emissions from the forestry sector. Mixed-species plantations are more resistant to disturbances such as storms, insects, or diseases; improving forest biodiversity at the stand scale and adopting modern and sustainable forest management and tending techniques are necessary.

Regarding climate-resilient forest ecosystems, forest ecosystem protection reduces the likelihood of zoonotic illnesses and worldwide pandemics. A sustainable future for humans, the earth, and prosperity is thus dependent on maintaining healthy, biodiverse, but resilient forests worldwide. Climate change still severely impacts China's monospecific and even-aged forests. Climate change has also revealed previously unknown vulnerabilities, exacerbating other catastrophic stresses, including diseases, insects, and pollution. It changes forest fire regimes, resulting in increased extent and intensity of forest fires, thereby rapidly accelerating climate and biodiversity crises.

Regarding the uncertain effects of CO_2 fertilization, the CO_2 fertilization effects will reduce the augmentation of the terrestrial carbon sink when the growth rate of atmospheric CO_2 slows or ceases, depending on worldwide climate change initiatives and actions. Carbon sinks caused by ecological engineering, such as afforestation, will drop when forest ecosystems mature and enter the late-successional stage.

As discussed above, science-based afforestation, reforestation, and forest management should be utilized to deliver and safeguard long-term carbon sinks. Policies and strategies must be developed by monitoring synergies between climate mitigation and other measures, especially measures of environmental protection, thus ensuring that climate action does not endanger other ecosystems. To successfully improve the forest carbon sinks and maximize their contribution to carbon neutrality, the route of forest carbon sinks should be maximized by resolving the problems of "when" and "where" in designing forest-related ecological engineering programs. Notably, programs under the framework of "the action plan for consolidating and improving the carbon sink", an essential sector of realizing China's carbon emissions, will peak by 2030, with net-zero emissions by 2060, a relatively stable status of carbon neutrality.

Analysis from the Socioeconomic Perspective

Regarding social awareness among the public, the whole society does not pay enough attention to the contribution and potential of the forestry sector in climate mitigation and carbon neutrality endeavor at present (Interviewee 2). Enterprises and the public should be encouraged to use wood and bamboo products instead of more carbon-intensive and environmentally unfriendly materials.

Furthermore, China's current domestic wood supply scarcity co-occurs with the growing wood and forest product timber production and consumption. The gap between providing other forest ecosystem services and their demand is enlarging. Due to the strict protection of natural forests coupled with the limited production potential of the young plantations, China's domestic timber production is likely to decline further shortly. Therefore, the gap between domestic timber supply and demand is growing. It is difficult but crucial to find a balance between protection and utilization.

Future forestry strategies for addressing climate change should focus on the value of ecological products and on changing the mindset from forest stock volume management to biomass accumulation in the forest ecosystem rather than considering carbon neutrality as an economic behavior. It is the primary goal and critical path of China's forestry development under ecological civilization construction. In order to diversify local economies and create jobs in rural regions, it is equally vital to ensure the availability of wood and promote non-wood, forest-based economic activity. Moreover, the dynamic balance should be established in complete adherence to the best available scientific data to fully unleash the potential of forests for the future.

Analysis from the Technical Perspective

The utilization of forest bioenergy has numerous benefits, such as providing renewable fuel for clean energy while saving landfill space, reducing waste, etc. It can enhance energy independence, security, reliability, rural economic development, and a reduction in greenhouse gases and other pollutants associated with fossil fuels. However, improving the energy conversion efficiency of biomass energy while reducing the negative impact on the environment is a bottleneck calling for technical solutions (Interviewee 3). This technical issue is a constraint that inhibits the widespread promotion of biomass energy.

The stand-scale carbon sink measurement is labor-intensive with low efficiency. Moreover, there is tremendous uncertainty in the estimation of regional-scale remote sensing, and there is no unanimous foundation model and no suitable carbon density measurement technique. Future forestry carbon sink measurement should be based on automatic integrated air-space-ground monitoring.

Likewise, the statistical accounting methods lack uniform standards; as a result, the existing academic literature differs in their findings, with a wide range that the carbon dioxide fixed by China's forest ecosystem can offset 5%-45% of annual anthropogenic emissions in China on average.

Model evaluations should similarly be updated. In the case of China's terrestrial ecosystems, any attempts to assess their carbon sink capacity under the "carbon neutrality" scenario must consider a low atmospheric CO_2 scenario and the resulting decreased impact of CO_2 fertilization.

Forest management technologies that take into account both forest products and service supply capacity should use the process-based forest model LandClim to examine the forest dynamic, and its goods and services function under various climate change and management scenarios, the inherent link between wood production and forest diversification, and the most valuable capability for goods and services.

CONCLUSIONS

Climate change and carbon neutrality are interconnected global issues. The forestry sector plays an essential role, and this paper's core is how to sustainably and effectively implement future forestry strategies for climate change toward carbon neutrality. The in-depth interviews successfully obtained a large amount of first-hand data on the challenges and recommendations for future forestry development.

Finally, through a multidimensional analysis, this study proposes recommendations for implementing a forestry strategy toward China's carbon neutrality. These recommendations include: environmentally, putting more emphasis on science-based, large-scale greening with sound scientific principles, improving forest quality by precise tending, establishing a more climate resilient and adaptative forest ecosystem, and curbing the spread of exotic pests in the forest through early warning; socioeconomically, promoting forestry carbon education and knowledge by social media, enhancing publicity and social awareness of wood and bamboo products via multiple platforms, and balancing the supply and demand of timber flexibly without sacrificing forestry economy growth; technically, improving the quality and stability of wood and bamboo products and extending their service life and carbon storage time, making a breakthrough in forest biomass thermochemical conversion and multi-coupling technology, optimizing forest carbon measurement and monitoring system, and carrying out research on the critical technology of forest sink enhancement.

Future forestry strategy should further emphasize the sustainability aspect within ecological boundaries, considering the changing climate, and the need to accelerate transformational changes, thus contributing to the Paris Agreement and the UN's 2030 Agenda for Sustainable Development and its Sustainable Development Goals.

Research Limitations and Future Studies

Climate change and carbon neutrality are global challenges covering economic, environmental, and social development. The study takes forestry strategy as an essential aspect. Still, substantial and parallel improvements and innovations are much needed across all other social and technological frontiers, and breakthroughs in the latter could be decisive in the long run.

Regarding the research scope, China has a complex terrain and vast territory, with cold, temperate subtropics and tropical climatic zones. The ecosystem diversities and land-use changes are highly complicated. Due to time and energy constraints, it is impossible to go into every detail on a regional level. Regarding the research methodology, there is a lack of quantitative research, which makes the study's results lack data support and insufficient rationality. In terms of synergies and trade-offs across other sustainable development goals, future studies can delve into mitigation options' co-benefits for climate change adaptation and possible adverse side effects. Further research can explore the scalability and adaptability of China's strategies to other geopolitical contexts, which could enhance the global relevance of the study.

SUPPLEMENTARY MATERIALS

The following supplementary materials are available online at https://doi.org/10.20900/jsr.20240063. Supplementary File: Questionnaire for officials in China.

DATA AVAILABILITY

All data generated from the study are available in the manuscript and from authors upon reasonable request.

AUTHOR CONTRIBUTIONS

Article conceptualization: SZ and CY; Methodology: HC and QW; Assessment and analysis: SZ; Writing (original draft preparation): SZ; Writing (review and editing): CY, HC, and QW; Supervision: CY and HC. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

ACKNOWLEDGMENTS

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2020S1A5C2A01092978).

REFERENCES

1. Wang F, Harindintwali JD, Yuan Z, Wang M, Wang F, Li S, et al. Technologies and perspectives for achieving carbon neutrality. The Innov. 2021;2(4):100180.
2. Canadell JG, Raupach MR. Managing forests for climate change mitigation. Science. 2008;320(5882):1456-7.
3. Wright RT, Boorse D. Environmental science: Toward a sustainable future. Boston (US): Pearson; 2017.
4. Liu Z, Deng Z, He G, Wang H, Zhang X, Lin J, et al. Challenges and opportunities for carbon neutrality in China. Nat Rev Earth Environ. 2021;3(2):141-55.
5. Mallapaty S. How China could be carbon neutral by mid-century. Nature. 2020;586(7830):482-3.
6. Xu C, Wang B, Chen J. Forest carbon sink in China: Linked drivers and long short-term memory network-based prediction. J Clean Prod. 2022;359:132085.
7. Chen X, Lin B. Towards carbon neutrality by implementing carbon emissions trading scheme: Policy evaluation in China. Energy Policy. 2021;157:112510.
8. Piao S, Yue C, Ding J, Guo Z. Perspectives on the role of terrestrial ecosystems in the 'carbon neutrality' strategy. Sci China Earth Sci. 2022;65(6):1178-86.
9. Fang J, Yu G, Liu L, Hu S, Chapin FS. Climate change, human impacts, and carbon sequestration in China. Proc Natl Acad Sci USA. 2018;115(16):4015-20.
10. Ke S, Qiao D, Zhang X, Feng Q. Changes of China's forestry and forest products industry over the past 40 years and challenges lying ahead. For Policy Econ. 2021;123:102352.
11. Carbon Neutrality Coalition. Plan of Action. Available from: https://carbon-neutrality.global/plan-of-action/. Accessed on 26 Sep 2024.
12. Net Zero Tracker. Available from: https://zerotracker.net/. Accessed on 10 Jul 2022.
13. Zhao X, Ma X, Chen B, Shang Y, Song M. Challenges toward carbon neutrality in China: Strategies and countermeasures. Resour Conserv Recycl. 2022;176:105959.
14. Moomaw WR, Law BE, Goetz SJ. Focus on the role of forests and soils in meeting climate change mitigation goals: summary. Environ Res Lett. 2020;15(4):045009.
15. Herold M, Johns T. Linking requirements with capabilities for deforestation monitoring in the context of the UNFCCC-REDD process. Environ Res Lett. 2007;2(4):045025.
16. Harris NL, Gibbs DA, Baccini A, Birdsey RA, de Bruin S, Farina M, et al. Global maps of twenty-first century forest carbon fluxes. Nat Clim Chang. 2021;11(3):234-40.
17. Food and Agriculture Organization of the United Nations. Global Forest Resources Assessment 2020. Available from: https://doi.org/10.4060/ca9825en. Accessed on 3 Sep 2022.
18. Lorenz K, Lal R. Carbon sequestration in forest ecosystems. Berlin (Germany): Springer Science & Business Media; 2009.

19. Li C, Liao Y, Wen X, Wang Y, Yang, F. The development and countermeasures of household biogas in northwest grain for green project areas of China. Renew Sustain Energy Rev. 2015;44:835-6.
20. Li MJ. Carbon stock and sink economic values of forest ecosystem in the forest industry region of Heilongjiang Province, China. J For Res. 2021;33(3):875-82.
21. Doelman JC, Stehfest E, Vuuren DP, Tabeau A, Hof AF, Braakhekke MC, et al. Afforestation for climate change mitigation: Potentials, risks and trade-offs. Glob Change Biol. 2019;26(3):1576-91.
22. Riahi K, Van Vuuren DP, Kriegler E, Edmonds J, O'neill BC, Fujimori S, et al. The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview. Glob Environ Change. 2017;42:153-68.
23. Arneth A, Harrison SP, Zaehle S, Tsigaridis K, Menon S, Bartlein PJ, et al. Terrestrial biogeochemical feedbacks in the climate system. Nat Geosci. 2010;3(8):525-32.
24. Cunningham SC, Mac Nally R, Baker PJ, Cavagnaro TR, Beringer J, Thomson JR, et al. Balancing the environmental benefits of reforestation in agricultural regions. Perspect Plant Ecol Evol Syst. 2015;17(4):301-17.
25. Irland LC. Timber Productivity Research Gaps for Extensive Forest Management. Small-Scale For. 2011;10(4):389-400.
26. Ameray A, Bergeron Y, Valeria O, Montoro GM, Cavard X. Forest Carbon Management: a Review of Silvicultural Practices and Management Strategies Across Boreal, Temperate and Tropical Forests. Curr For Rep. 2021;7(4):245-66.
27. Ford-Robertson FC. Terminology of forest science, technology, practice & products (Multilingual forestry terminology series). Bethesda (US): Society of American Foresters; 1983.
28. Tong X, Brandt M, Yue Y, Ciais P, Rudbeck JM, Penuelas J, et al. Forest management in southern China generates short term extensive carbon sequestration. Nat Commun. 2020;11(1):1-10.
29. Dixon RK, Solomon AM, Brown S, Houghton RA, Trexier MC, Wisniewski J. Carbon Pools and Flux of Global Forest Ecosystems. Science. 1994;263(5144):185-90.
30. Griscom BW, Adams J, Ellis PW, Houghton RA, Lomax G, Miteva DA, et al. Natural climate solutions. Proc Natl Acad Sci USA. 2017;114(44):11645-50.
31. World Economic Forum. The Number of Cars Worldwide Is Set to Double by 2040. Available from: https://www.weforum.org/agenda/2016/04/the-number-of-cars-worldwide-is-set-to-double-by-2040/. Accessed on 26 Sep 2024.
32. Rudel TK, Defries R, Asner GP, Laurance WF. Changing drivers of deforestation and new opportunities for conservation. Conserv Biol. 2009;23(6):1396-405.
33. van der Werf GR, Randerson JT, Giglio L, van Leeuwen TT, Chen Y, Rogers BM, et al. Global fire emissions estimates during 1997–2016. Earth Syst Sci Data. 2017;9(2):697-720.
34. Friedlingstein P, Jones MW, O'Sullivan M, Andrew RM, Hauck J, Peters GP, et al. Global Carbon Budget 2019. Earth Syst Sci Data. 2019;11(4):1783-838.

35. Zheng B, Ciais P, Chevallier F, Chuvieco E, Chen Y, Yang H. Increasing forest fire emissions despite the decline in global burned area. Sci Adv. 2021;7(39):eabh2646.
36. Quirion BR, Domke GM, Walters BF, Lovett GM, Fargione JE, Greenwood L, et al. Insect and Disease Disturbances Correlate With Reduced Carbon Sequestration in Forests of the Contiguous United States. Front For Glob Change. 2021;4:716582.
37. Kurz WA, Stinson G, Rampley GJ, Dymond CC, Neilson ET. Risk of natural disturbances makes future contribution of Canada's forests to the global carbon cycle highly uncertain. Proc Natl Acad Sci USA. 2008;105(5):1551-5.
38. Hertwich EG, Ali S, Ciacci L, Fishman T, Heeren N, Masanet E. Mterial efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics—a review. Environ Res Lett. 2019;14(4):043004.
39. US FOREST SERVICE (USFS). CORRIM report on environmental performance measures for renewable building materials: FS 20050601-1. Madison (US): USDA Forest Service, Forest Products Laboratory; 2005.
40. Zhou G, Liu S, Li Z, Zhang D, Tang X, Zhou C, et al. Old-Growth Forests Can Accumulate Carbon in Soils. Science. 2006;314(5804):1417.
41. International Energy Agency. Technology Roadmap: Delivering Sustainable Bioenergy. Paris (France): IEA; 2017.
42. Liao S, Wang D, Xia C, Tang J. China's provincial process CO_2 emissions from cement production during 1993–2019. Sci Data. 2022;9(1):165.
43. World Steel Association. World steel in figures 2019. Available from: https://worldsteel.org/wp-content/uploads/2019-World-Steel-in-Figures.pdf. Accessed on 26 Sep 2024.
44. Tollefson J. The wooden skyscrapers that could help to cool the planet. Nature. 2017;545(7654). doi: 10.1038/545280a
45. Suter F, Steubing B, Hellweg S. Life Cycle Impacts and Benefits of Wood along the Value Chain: The Case of Switzerland. J Ind Ecol. 2016;21(4):874-86.
46. Pittau F, Lumia G, Heeren N, Iannaccone G, Habert G. Retrofit as a carbon sink: The carbon storage potentials of the EU housing stock. J Clean Prod. 2019;214:365-76.
47. Oliver CD, Nassar NT, Lippke BR, McCarter JB. Carbon, Fossil Fuel, and Biodiversity Mitigation With Wood and Forests. J Sustain Forestry. 2014;33(3):248-75.
48. Kallio M, Chen, X, Jonsson R, Kunttu J, Zhang Y, Toppinen A, et al. China-Europe Forest Bioeconomy: Assessment and Outlook. Sci Policy. 2020;11. doi: 10.36333/fs1
49. Yeh S, Witcover J, Lade GE, Sperling D. A review of low carbon fuel policies: Principles, program status and future directions. Energy Policy. 2016;97:220-34.
50. Ilari A, Duca D, Boakye-Yiadom KA, Gasperini T, Toscano G. Carbon Footprint and Feedstock Quality of a Real Biomass Power Plant Fed with Forestry and Agricultural Residues. Resources. 2022;11(2):7.

51. Titus BD, Brown K, Helmisaari HS, Vanguelova E, Stupak I, Evans A, et al. Sustainable forest biomass: a review of current residue harvesting guidelines. Energy Sustain Soc. 2021;11:1-32.
52. World Bioenergy Association. Global bioenergy statistics 2019. Stockholm (Sweden): World Bioenergy Association; 2019.
53. English BC, Ugarte DDLT, Jensen K, Hellwinckel C, Menard J, Wilson B, et al. 25% renewable energy for the United States by 2025: Agricultural and economic impacts. Available from: https://www.25x25.org/storage/25x25/documents/RANDandUT/UT-EXECsummary25X25FINALFF.pdf. Accessed on 26 Sep 2024.
54. Malmsheimer RW, Heffernan P, Brink S, Crandall D, Deneke F, Galik C, et al. Forest management solutions for mitigating climate change in the United States. J For. 2008;106(3):115-73.
55. China Green Times. Interpretation of forests as reservoir. Available from: http://www.forestry.gov.cn/main/586/20220415/093613846691966.html. Accessed on 11 Aug 2022.
56. China Green Times. Interpretation of forests as money bank. Available from: http://www.forestry.gov.cn/main/586/20220420/085520434899596.html. Accessed on 11 Aug 2022.
57. China Green Times. Interpretation of forests as grain reserves. Available from: http://www.forestry.gov.cn/main/586/20220418/091339205588070.html. Accessed on 11 Aug 2022.
58. China Green Times. Interpretation of forests as carbon pool. Available from: http://www.forestry.gov.cn/main/586/20220422/091340305866550.html. Accessed on 11 Aug 2022.
59. Wang B, Niu X, Song QF. Analysis of forest carbon sequestration capacity in China based on forest full-aperture carbon sequestration. Environ Prot. 2021;49(16):30-4.
60. China National Forestry and Grassland Administration. China Forest Resources Report. Beijing (China): China Forestry Publishing House; 2018.
61. National Forestry and Grassland Administration. 14th Five-Year-Plan of Forestry and Grassland. Available from: http://www.forestry.gov.cn/c/www/lczc/44287.jhtml. Accessed on 26 Sep 2024.
62. National Forestry and Grassland Administration. Forestry as Strategic Choice to Address Climate Change. Available from: http://www.forestry.gov.cn/main/61/20171226/1061501.html. Accessed on 11 Aug 2022.

How to cite this article:
Zhao S, Yeom C, Cai H, Wang Q. Assessing Forestry Strategy for Addressing Climate Change and its Challenges toward Carbon Neutrality in China. J Sustain Res. 2024;6(3):e240063. https://doi.org/10.20900/jsr20240063