Prospects and challenges for land-based climate change mitigation in support of carbon dioxide removal in China

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Summary

Reducing greenhouse gas emissions from land and harnessing land's carbon sequestration potential have not been addressed in China to the same extent as climate mitigation in other sectors such as energy and industry. Where existing land use policies have effects on emissions or carbon sequestration, the majority of examined policies primarily feature indirect indicators or targets related to carbon sequestration. Consequently, the development of land-based mitigation technologies and practices (LMTs) often occurs by default rather than as a deliberate outcome of policy design, as illustrated in this report.

Among land use and ecosystem types, forestry has received the most attention in China for its contribution to carbon sequestration through afforestation, forest management, and forest restoration. This is reflected in the amount of policy documents, including China's nationally determined contribution (NDC), presenting plans, targets and indicators for the forestry sector.

The 2022 launch of the Agriculture and Rural Areas Emission Reduction and Carbon Sequestration Implementation Plan demonstrates the intention to address the rising emissions and considerable sequestration potential in the agricultural sector. However, this is a recent development, and detailed indicators and targets on carbon sequestration are yet to be devised.

Other currently underexploited opportunities for land carbon sequestration and emission reductions include land use management of grasslands and wetlands, as well as industrial applications such as biochar and bioenergy with carbon capture and storage (BECCS); although generally recognized for their carbon sequestration potential, these do not yet appear to be present in the Chinese climate change mitigation policy landscape. Their relevance is likely to increase as the area for wider forest expansion saturates.

Increased attention for the emissions and sequestration potential from the land sectors will be necessary on China's decarbonization pathway and journey to reach net-zero by 2060. More focus on these sectors is expected in the future especially after China reaches its carbon peak, currently planned for 2030. This will entail improving policy frameworks, methodologies, incentives schemes, and implementation practices across land sectors. The restart of the China Certified Emission Reduction (CCER) trial scheme in 2023 is an example of an instrument that may further financing and implementation of LMTs, albeit currently largely limited to the forestry sector.

While each LMT exhibits distinct advantages and development barriers, a common challenge across many LMTs is the absence of knowledge, technical readiness, and standardized procedures for implementation. Therefore, apart from policy support from the government, there is an opportunity for both domestic and international research institutes to contribute by enhancing capacity and sharing knowledge in this domain. Research is needed, for example, on how to incentivize farmers efficiently through policies with adequate subsidy strategies and support systems with training and technical assistance that facilitate the uptake of LMTs.

1. Introduction

To limit climate change to less than 1.5° or 2°C globally requires significant and urgent mitigation efforts across all socio-economic sectors, including carbon dioxide removal or negative emissions, for which most current efforts are concentrated in the land sectors. Land-based mitigation technologies and practices (LMTs), if implemented at scale, could provide an estimated 20–30% of the mitigation required globally. Such interventions in forestry, agriculture, and grasslands and wetlands management also bring a large number of co-benefits relating to biodiversity, water quality and availability, and more (Roe et al., 2021).

China is one of the countries where LMTs have the most significant and cost-effective potential (Roe et al., 2021). Its land area, which is similar in size to the US and more than twice that of the EU, harbours a diverse array of climatic conditions and is home to a majority of the world's vegetation types (Fang et al., 2018).

The high potential of LMTs in China suggests alternative long-term emission trajectories that could transform China into a net sink for greenhouse gas emissions. However, as in most countries, the focus in China for climate change mitigation has been on energy, industry, infrastructure and transport rather than land use (Ding et al., 2023). As a result of the lack of focus on land use emissions, including major drivers such as land use conversion and agricultural production due to changing diets, agricultural emissions in China are projected to rise further and to become one of the primary sources of greenhouse gases in the future (Chen et al., 2023; Ding et al., 2023). Within the land use sectors, the forestry sector has received more attention in past decades for its emission mitigation potential, but unlimited expansion of forest cover is not possible due to lack of suitable and available land (Ding et al., 2023).

To limit the extent to which land-based emissions grow, and to harness the potential of LMTs as part of the wider climate change efforts towards China's 2060 net-zero goal, it is important that they are investigated and implemented at scale in the near-to-medium-term. Efforts have been made to model the future evolution of land-based climate change mitigation in China. The computer models, however, have not been able to provide a unified answer to where China is headed due to different data and assumptions on inputs such as growth rates, afforestation and deforestation, emission factors, and so forth (Chen et al., 2023). Also, the policy landscape in China is not unified when it comes to land use, since no overarching land use policy or roadmap has been established (Chen et al., 2023).

To get an improved understanding of the current status of land-based mitigation in China, as well as the direction in which the country is moving, we analysed published scientific literature and Chinese policy documents containing information, qualitative statements and quantitative targets, pertaining to the development of LMTs. To explore future trends, we interviewed experts including researchers and practitioners in the Chinese land use and climate mitigation sphere, gathering their insights on the enablers and barriers to the development and implementation of LMTs.

In section 2, we provide an overview of China's greenhouse gas emissions, and its land-based carbon stocks and flows, where we spotlight mitigation potential for LMTs based on the published literature. In section 3, we provide an analysis of LMT-related policies. Section 4 presents the perspectives on LMT development and future trends from experts. Finally, section 5 provides a discussion and conclusions based on the policy analysis and experts' insights.

2. Background

2.1 China's emission profile

Energy, electricity, manufacturing and construction, industrial processes, and transportation made up 90% of China's emissions in 2020 (Figure 1; Climate Watch, 2021). Agriculture played a modest role, at 3% of total emissions (Figure 1). Most emissions within agriculture in China come from enteric fermentation, rice cultivation, synthetic fertilizer application and manure management (Figure 2; FAO, 2020; *FAOSTAT*, 2021). The forestry sector is an emission sink, according to FAO data: in 2020, forest carbon removal compensated for nearly all greenhouse gas emissions stemming from agriculture (Figure 2).

The agricultural sector has generally not been prioritized for decarbonization efforts in China, and agricultural emissions are expected to make up a larger share of China's total emissions in the future (Chen et al., 2022). If forests lose their capacity to compensate for equal or increasing amounts of greenhouse gas emissions from all land sectors, then emissions overall from land use will increase in absolute terms, potentially making the land sector another emitter in China.

Figure 1. China 2020 greenhouse gas emissions by sector
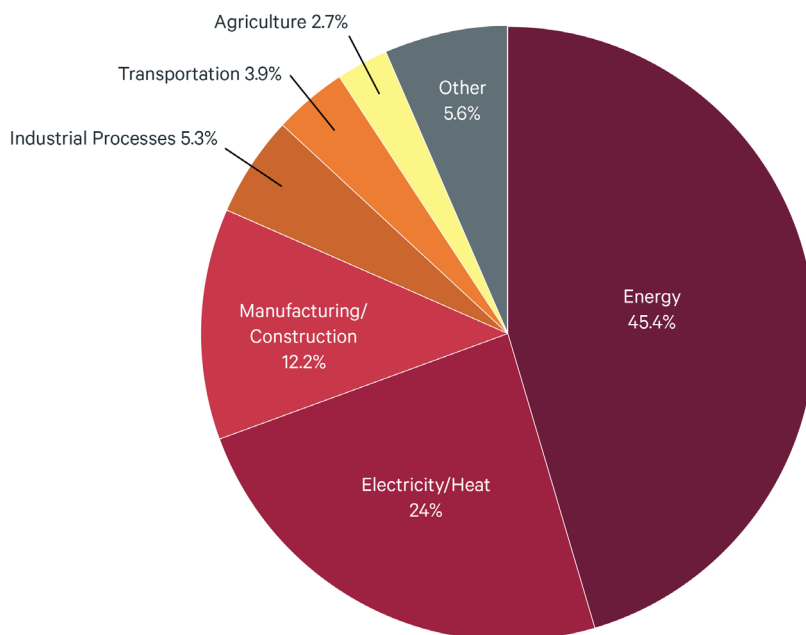
Source: Climate Watch (2021)

Note: "Other" includes fugitive emissions (2.6%), building (2.1%), Waste (0.9%), other fuel combustion (0.7%) and bunker fuels (0.2%).

Figure 2. China 2020 agricultural, forestry and other land use (AFOLU) carbon emissions and sequestration
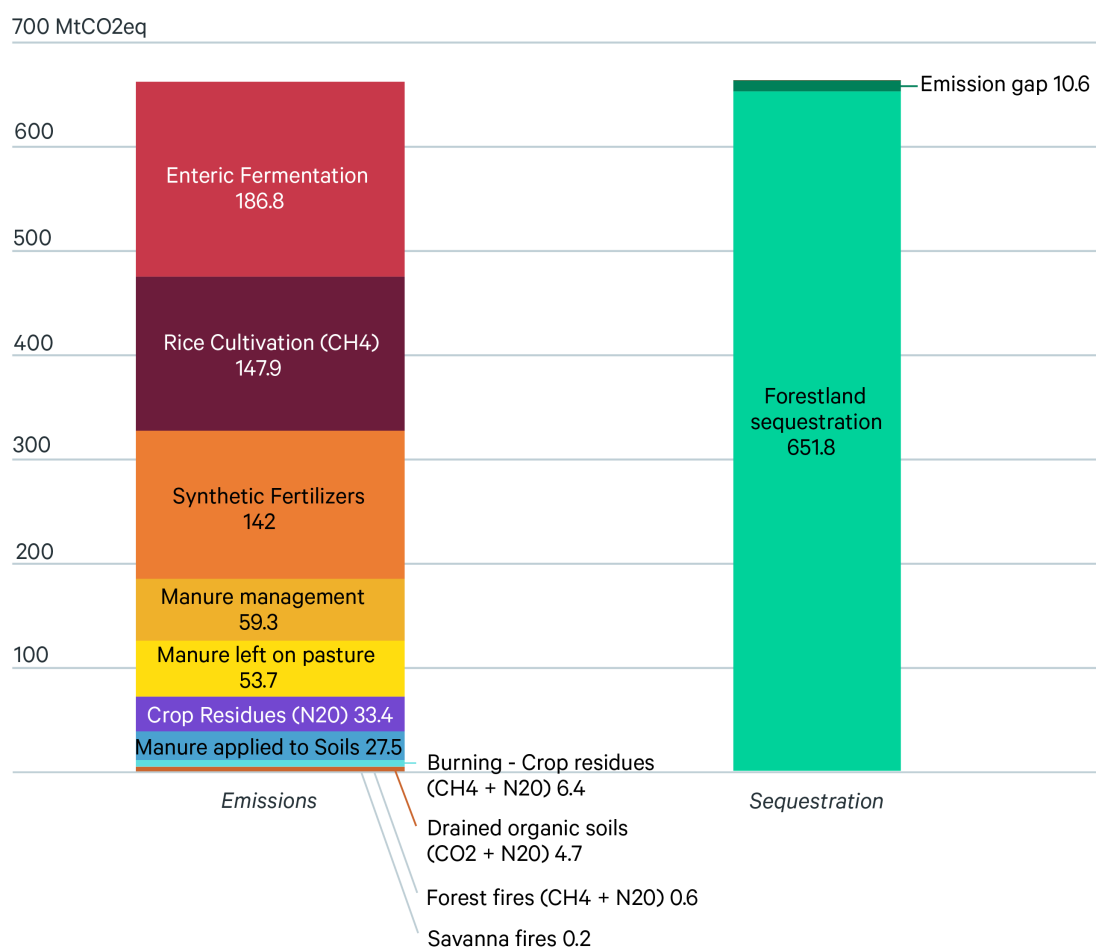
Source: FAOSTAT (2021)

Note: FAOSTAT methodology does not include carbon sequestration from grasslands, while grassland emissions are included under certain categories such as emissions from fertilizers, fires and soil draining. Emissions and sequestration from wetlands are not included.

2.2 Land-based carbon stocks and flows in China

Past land use changes driven by economic development, such as the conversion of forest or other wild lands into agricultural lands in northern China, have exerted pressures on the natural environment, leading to water availability issues among other challenges (Fang et al., 2018). Besides land use changes, land management practices have caused environmental damage in the past and continue to do so at present. China, which feeds a fifth of the global population, is responsible for a third of global chemical fertilizer use and a quarter of global pesticide use (Fang et al., 2018). China's land management practices have led to widespread air, water and soil pollution; soil erosion; and biodiversity loss (Fang et al., 2018).

At the same time, over the past several decades, other efforts in land sectors have created a significant carbon sink, even though they have not always been implemented with carbon sequestration as the primary objective. Examples include large restoration and protection programs, especially in the form of afforestation and reforestation (Fang et al., 2018; Lu et al., 2022). In agriculture, decades of policy-driven crop residue management have significantly increased soil organic carbon in cropland soils (Fang et al., 2018).

Funded by the government, the Chinese Academy of Sciences implemented a five-year Strategic Priority Project of Carbon Budget. The aim of the research project was to fill data gaps that would answer the following questions: how much carbon is stored in the different land use types in China and how do human and natural factors influence sequestration? And what has been the effect on carbon stocks from past efforts such as the major ecological restoration projects and altered agricultural management practices (Fang et al., 2018)? Field experiments were conducted on forests, grasslands, shrublands and croplands across the country; the field data were combined with remote sensing data, and the results were extrapolated to the country level. The study found that the carbon stock of these terrestrial ecosystems amounts to 79.24 Petagrams of carbon (Pg C). The distribution is 39% in forests; 32%, grasslands, 8%, shrublands; and 21%, croplands, as shown in Table 1, which also shows the land areas and the carbon stock changes for the period 2001–10 in the same ecosystems. Additionally, carbon pool estimations for other terrestrial ecosystems from prior studies are added.

Interestingly, Fang et al. (2018) also showed that both carbon density and the proportion of ecosystem carbon in plant biomass are lower than in other countries, reflecting past human disturbances in China. This suggests the potential to increase carbon stocks with appropriate management.

Table 1. Area, carbon pool and carbon stock change for terrestrial ecosystems in China

	Forest	Shrubland	Grassland	Cropland	Wetlands	Built-up land	Other land	Total
Area (million hectares or 10^6 ha)	188.2	74.3	281.3	171.3	35.6	25.3	9.5	785.5
Carbon pool (Petagrams of carbon, Pg C)	30.8	6.7	25.4	16.3	6.5	1.9	2.1	89.7
Carbon stock change, from 2001 to 2010 (Teragrams of carbon, Tg C, per year)	163.4	17.1	−3.4	23.9	No data	No data	No data	201.1

Source: combined data from Fang et al. (2018) and Tang et al. (2018)

2.3 Potential for land-based mitigation in China

Forestry is the crucial land sector for climate change mitigation in China, both historically and in the future. Afforestation and reforestation will further contribute to decreasing emissions and sequestering carbon, but less so as the availability of land for new forests is limited by water availability and by land requirements for agriculture and urbanization (Lu et al., 2022). In the future, the largest additional mitigation potential in forestry will come from better forest management and protection of natural forests from logging. Due to policies in place, the risk of conversion of forests to other land uses, as well as the risk of wildfires, is minor in China (Lu et al., 2022). China's nationally determined contribution (NDC) target of a 6 billion m^3 increase in forest stock volume by 2030 compared to 2005 levels has been deemed achievable (Lu et al., 2022).

Agriculture offers considerable future potential for climate mitigation, both for reducing greenhouse gas emissions and for carbon sequestration. The largest part of this potential comes from enhanced cropland nutrient management, which decreases emissions of nitrous oxide from synthetic fertilizers, a key source of greenhouse gas emissions in the agriculture sector (Lu et al.,

2022). The agriculture sector in China could increase carbon sequestration by use of cover crops and decrease methane emission reductions through improved rice cultivation, given the large area used to produce rice (Lu et al., 2022).

Biochar implementation is currently very limited in China and is not expected to become a widely applied solution soon (Lu et al., 2022), even though the technical potential of sequestering greenhouse gases with biochar has been acknowledged. Experts think it will play a future role, and several policies do mention it.

The carbon sequestration potential of grasslands is smaller than that of forestry and agricultural land or cropland. However, it can be enhanced by restoring degraded grasslands, avoiding conversion of grasslands to farmland, and optimizing grazing practices (Lu et al., 2022).

Finally, wetlands, and peatlands in particular, have climate change mitigation potential. Preventing their loss and restoring or rewetting them can be pursued to harness their potential as carbon sinks (Lu et al., 2022).

With these potentials and limitations in mind, we reviewed policies and elicited expert views on potential LMT development in the following areas: forestry, agriculture, agroforestry, biochar, grasslands and wetlands. We also examined the China Certified Emission Reduction (CCER) scheme, particularly the trial relaunched in 2023. The CCER is relevant as it signals the adoption of market mechanisms for LMTs, thereby potentially contributing to their development.

3. Policy review and analysis

We conducted a review of existing policies in order to establish a more comprehensive view on the status of and trends in the implementation of land-based climate mitigation technologies and practices in China. The 42 policies assessed in this section are listed in Table 2, with corresponding numbers used to refer to them in superscript throughout the discussion. For further details on the issuing authority, thematic and temporal scope, and targets, see Annex 1.

We also assessed the development status of each LMT (Table 3) by examining various aspects of policy status. This includes evaluating the policy recognition status of each LMT, determining if there is a dedicated national plan for specific LMTs, assessing whether their targets impact carbon sequestration and whether they were set for that reason, checking if they are mentioned in the NDC, reviewing the implementation of projects, and verifying their inclusion in CCER.

In 2021, the State Council of China officially recognized forests, grasslands, wetlands, oceans, soils, permafrost and karst as critical components of carbon sequestration ecosystems[1]. This recognition marked a pivotal moment in China's commitment to maintaining and enhancing the carbon sequestration capacity of its ecosystems.

The policy[1] encompasses a range of initiatives, including restoration projects, the consolidation of efforts to convert farmland back to forests and grasslands, improved forestry management practices, and measures aimed at enhancing soil quality, such as the implementation of the national black soil protection project. Additionally, the policy includes efforts to increase carbon sequestration in "eco-agriculture".

The timeline in Figure 3 displays an overview of key LMT-related targets that were obtained from the reviewed policies. It shows that some land sectors, such as forestry, have received more attention, which translates into more varied and long-term indicators and targets.
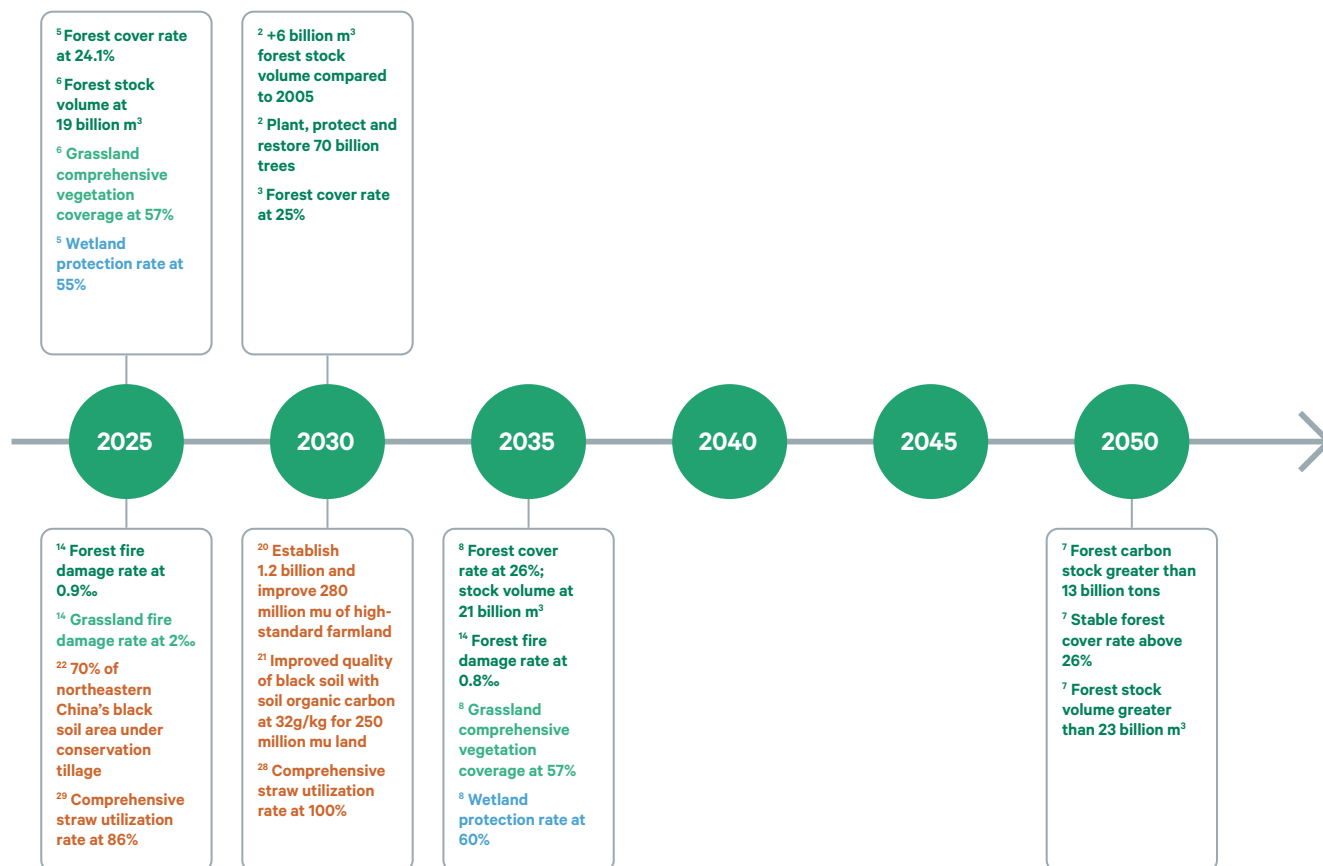
Table 2. Documents reviewed for policies on land use in China, with corresponding numbers used as identification in the text below

	Document name in English, translated from the original Chinese title	Year published
1	China's Policies and Actions for Addressing Climate Change	2021
2	China's implementation of NDC and progress report	2022
3	China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy	2021
4	China's Action Plan for Reaching Peak Carbon Emissions by 2030	2021
5	China's 14th Five-Year Plan (2021–25)	2021
6	Outline of the 14th Five-Year Forestry and Grassland Protection and Development Plan	2021
7	National Forest Management Plan (2016–50)	2016
8	National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems (2021–35)	2021
9	General Plan for the Three-North Shelterbelt System Construction Project	2022
10	14th Five-Year Plan on Village Greening Program	2022
11	Fujian Province Land Greening Plan	2022
12	National Sustainable Forest Management Pilot Implementation Plan (2023–25)	2023
13	Sichuan Province's Work Plan for Promoting National Sustainable Forest Management Pilot Work Plan (2023–25)	2023
14	Ecosystem Protection and Repairment Plan (2021–35)	2021
15	Northeast Forestry Plan (2021–35)	2021
16	Northern Sand Prevention Belt Protection and Repairment Plan (2021–35)	2021
17	Plan of Dry Land in Southern Mountain and Hilly Region (2021–35)	2021
18	Daxiao Xing'an Mountain Forest Plan (2021–35) and 14th Five-Year Plan on Daxiao Xing'an Mountain	2021
19	Agricultural and Rural Emission Reduction and Carbon Sequestration Implementation Plan	2022
20	National High-Standard Farmland Construction Plan	2021
21	Northeast Black Land Protection Planning Outline (2017–30)	2017
22	Northeast Black Land Conservative Cultivation Action Plan (2020–25)	2020
23	National Black Soil Protection Project Implementation Plan (2021–25)	2021
24	Black Soil Protection Law of the People's Republic of China	2022
25	Heilongjiang Province's 14th Five-Year Plan for Black Land Protection	2021
26	Jilin Province Black Soil Protection Master Plan (2021–25)	2021
27	Action Plan for Substituting Chemical Fertilizers with Organic Fertilizers for Fruit, Vegetable and Tea	2017
28	National Plan for Sustainable Agricultural Development (2015–30)	2015
29	14th Five-Year Plan on National Green Agricultural Development	2021
30	Notice of the General Office of the Ministry of Agriculture and Rural Affairs on Doing a Good Job in the Comprehensive Utilization of Crop Straws in 2022	2022
31	Guiding Opinions on Comprehensive Utilization of Bulk Solid Waste during the "14th Five-Year Plan"	2021
32	The Central State Organs on Doing a Good Job in Key Works in the "Three Rural" Fields to Ensure Realize the meaning of a well-off society in an all-round way as scheduled	2020
33	Glasgow Joint Declaration between China and the US on Enhancing Climate Action in the 2020s	2021
34	National Water-Saving and Drought-Resistant Rice Industry Chain Innovation Alliance, established in Tianjin	2023
35	National Understory Economic Development Guide (2021–30)	2021
36	Notice on Strengthening the Construction and Management of Farmland Protection Forests	2022
37	List of Top 10 Leading Technologies of the Ministry of Agriculture and Rural Affairs in 2020	2020
38	The Third Round of Grassland Ecological Protection Subsidy and Incentive Policies Interpretation	2021
39	National Wetland Conservation Plan (2022–30)	2022
40	National Soil and Water Conservation Plan (2015–30)	2015
41	Opinions on Strengthening Soil and Water Conservation Work in the New Era	2023
42	Notice on the issuance of four methodologies including the "Methodology for Voluntary Greenhouse Gas Emission Reduction Projects – Afforestation Carbon Sink"	2023

Source: Authors' own

Note: See Annex 1 for more information about each document, including the issuing authority, thematic and temporal scope, targets and link to access original policy.

Figure 3. Timeline overview of key LMT-related policies (as listed by number in Table 2) and targets

[5] **Forest cover rate at 24.1%**

[6] **Forest stock volume at 19 billion m³**

[6] **Grassland comprehensive vegetation coverage at 57%**

[5] **Wetland protection rate at 55%**

[2] **+6 billion m³ forest stock volume compared to 2005**

[2] **Plant, protect and restore 70 billion trees**

[3] **Forest cover rate at 25%**

2025   2030   2035   2040   2045   2050

[14] **Forest fire damage rate at 0.9‰**

[14] **Grassland fire damage rate at 2‰**

[22] **70% of northeastern China's black soil area under conservation tillage**

[29] **Comprehensive straw utilization rate at 86%**

[20] **Establish 1.2 billion and improve 280 million mu of high-standard farmland**

[21] **Improved quality of black soil with soil organic carbon at 32g/kg for 250 million mu land**

[28] **Comprehensive straw utilization rate at 100%**

[8] **Forest cover rate at 26%; stock volume at 21 billion m³**

[14] **Forest fire damage rate at 0.8‰**

[8] **Grassland comprehensive vegetation coverage at 57%**

[8] **Wetland protection rate at 60%**

[7] **Forest carbon stock greater than 13 billion tons**

[7] **Stable forest cover rate above 26%**

[7] **Forest stock volume greater than 23 billion m³**

3.1 Forestry

Forestry plays an essential role in China's pursuit of carbon sequestration and is the focus area of the country's climate-related objectives in terms of ecosystem carbon sinks. This prominence is reflected in the large number of policies that set targets for the sector, including the updated NDC[2] submitted in 2022, the Strategy for China's Mid-Century Low Greenhouse Gas Development[3], China's Action Plan for Reaching Peak Carbon Emissions by 2030[4], China's 14th Five-Year Plan (2021–25)[5], the Outline of the 14th Five-Year Forestry and Grassland Protection and Development Plan[6], and the National Forest Management Plan[7].

These policies underscore China's commitment to expanding, enhancing and protecting forests as integral components of ecological restoration and sustainable development. The National Forest Management Plan[7] includes an explicit carbon sequestration target of storing more than 13 billion metric tons of carbon in forests by 2050.

It is worth highlighting that, although the National Forestry and Grassland Bureau oversees other ecosystems, the NDC was issued by the Ministry of Ecology and Environment, signalling the determination of the central government through an international commitment. The State Council itself released the Low Greenhouse Gas Development Strategy, demonstrating the highest level of government support for advancing forest development.

On examining China's forestry policy framework, three key strategies present themselves that serve as LMTs: afforestation, forest management, and forest protection and restoration.

Afforestation

The expansion of forest cover through afforestation remains a central strategy in China. As laid out consistently in multiple policies and plans, China aims to achieve a forest cover rate of 24% by 2025[5,6], 25% by 2030[3,4] by planting an additional 70 billion trees[2], 26% by 2035[8], and a stable national forest cover rate of over 26% by 2050[7]. Additionally, there is a target for nature reserves, dominated by national parks, to cover more than 18%[6] of the land area by 2025, as well as a target to keep natural forest area stable at about 200 million hectares (ha)[8].

China has carried out various large-scale afforestation programs in the past and several are still ongoing. One example is the Three-North Shelterbelt System Construction Project[9], which has the long-term goal of combating desertification by afforesting over 35 million ha by 2050. China's 14th Five-Year Plan included a greening program[10] designed to promote rural development aims at planting more than 1.5 billion trees near villages.

Forest management

In addition to expanding forest cover, China is now focused on forest management to enhance the quality and volume of existing forest areas. Various policies and plans set the country's aims increase the forest stock volume: 19 billion m^3 by 2025[6]; a 6 billion m^3 increase compared to 2005 levels by 2030[2]; exceeding 21 billion m^3 by 2035[8]; and exceeding 23 billion m^3 by 2050[7]. In response to national targets, subnational forestry management plans are proposed to enhance forest quality and increase forest carbon sequestration capacity. For instance, Fujian Province aims to raise the forest stock volume per unit area to 122.00 in 2025 from 121.64 in 2020 and maintain a steady increase from 2025 to 2030[11].

In addition to increasing the forest stock volume, higher standards for forestry management areas are being implemented[7]. In 2023, China introduced the National Sustainable Forest Management Pilot Implementation Plan (2023–25)[12] as guidance for forest management. This plan encourages the exploration of business models for state-owned forests to sequester carbon and enhance carbon sinks. Complementing national policies, Sichuan Province issued its Sustainable Forest Management Pilot Work Plan[13], setting the quantitative targets for the province.

Forest protection and restoration

Forestry restoration also plays a crucial role in achieving carbon neutrality by preventing carbon emissions resulting from tree logging or damage. In 2021, China releas ed the National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems (2021–35)[8], with a significant focus on forestry. Corresponding ecosystem protection and restoration plans[14] aim to control damage rates, forest fires, and the incidence of forestry pests. In response to these national policies, various regions have issued corresponding planning policies tailored to their unique ecosystem characteristics, including the northeast[15], the northern sand prevention belt[16], the drylands in the southern mountain and hilly regions[17], and the Daxiao Xing'an Mountain Forest[18].

3.2 Agriculture

Reviewing China's agricultural policy framework, it becomes evident that while overall it does not set specific targets for carbon sequestration within the agricultural sector, it incorporates measures such as those mentioned below that encourage actions that enhance carbon sequestration. A pivotal new policy for reducing emissions within the agricultural sector is the Agriculture and Rural Areas Emission Reduction and Carbon Sequestration Implementation Plan[19]. Launched in 2022, the plan prioritizes several key initiatives for arable lands, promoting rice paddy methane emission reduction, increasing soil organic matter, fertilizer reduction and efficiency improvement, biochar application, and the adoption of conservation farming practices such as stubble retention, organic fertilizer application and green manure planting. The plan also recognizes the carbon sequestration potential in specific production systems such as orchards and tea gardens.

In 2021, the Ministry of Agriculture and Rural Affairs introduced the National High-Standard Farmland Construction Plan[20]. This initiative aims to bolster food security by creating high-yield, eco-friendly, high-standard farmland. The proposed actions, such as increasing the organic matter content in the soil and enhancing irrigation facilities, can also potentially increase the land's carbon sequestration capacity and improve methane management in rice cultivation.

Black soil protection

Black soil protection promotes conservation and no-tillage practices, particularly in China's northeast region where soil with high carbon storage capacity is predominantly present. Notably, in 2017, the Ministry of Agriculture and Rural Affairs issued the Northeast Black Soil Protection Planning Outline[21], detailing objectives related to black soil protection, cultivated land quality and soil organic matter content. The aim is to protect an area of 16.6 million ha (250 million mu) by 2030[21]. In 2020, the Northeast Black Soil Conservation Cultivation Action Plan[22] was introduced to promote conservation tillage, with the goal of implementing conservation tillage on 70% of total arable land, equivalent to 9.3 million ha (140 million mu), by 2025.

China further reinforced its commitment with the issuance of the National Black Soil Protection Project Implementation Plan (2021–2025)[23] and the enactment of targeted legislation, the Black Soil Protection Law[24], underscoring strong governance and legal support for black soil protection. Following the national commitment, provinces in the northeast region, such as Heilongjiang[25] and Jilin[26], issued Black Soil Protection Master Plans for the period 2021 to 2025.

Organic fertilizer

Sustainable agriculture policies emphasize the use of organic fertilizers, particularly in fruit, vegetable and tea cultivation. Specific policies targeting organic fertilizer use were introduced through initiatives like the Action Plan for Substituting Chemical Fertilizers with Organic Fertilizers for Fruit, Vegetable and Tea[27], issued in 2021. Organic fertilizer adoption such as utilization of poultry manure is also encouraged in broader sustainable agriculture[28] and green agriculture development plans[29], as well as rural modernization plans.

Comprehensive straw utilization

The carbon sequestration benefits of comprehensive straw utilization have been recognized in the Notice of Comprehensive Straw Utilization[30]. Multiple policies advocate for the comprehensive use of straw, and the set target is to achieve an 86% utilization rate by 2025[29]. Initiatives include the Comprehensive Utilization of Bulk Solid Waste[31], green agriculture practices[29], and others applicable to the Three Rural Fields[32], namely: agriculture, rural areas and farmers.

Rice cultivation

As of now, no targeted policies address methane emissions from rice paddies. However, the Glasgow Joint Declaration between China and the US on Enhancing Climate Action in the 2020s[33] committed to methane emission control.

Additionally, the National Water-Saving and Drought-Resistant Rice Industry Innovation Alliance established in 2023 aims to reduce emissions from rice cultivation by 20 million tons CO_2eq. Plans are to replace traditional paddy rice planting methods with newly developed rice breeds that are water-saving and drought resistant, allowing for a 30% reduction in fertilizer reduction and a 90% reduction in methane emissions[34].

3.3 Agroforestry

Agroforestry has gained prominence as a strategy promoted by the National Forestry and Grassland Administration for farmland protection and understory economic development. The National Understory Economic Development Guide (2021–30)[35] sets ambitious targets, aiming to achieve a total area of forest land under economic management and utilization of 263 million ha by 2025 and reach 304 million ha by 2030. In 2022, the National Forestry and Grassland Administration recognized the potential of forestry and grassland ecological protection and restoration to serve as farmland shelterbelts, thereby promoting the development of high-standard farmland[36].

3.4 Biochar

Biochar was recognized in the "List of Top 10 Leading Technologies"[37] issued by the Ministry of Agriculture and Rural Affairs in 2020 for its potential as an organic fertilizer. However, specific policies directly promoting it are currently lacking.

3.5 Grasslands

Grasslands management has been acknowledged as an LMT in China's Policies and Actions for Addressing Climate Change[1]. Existing policies target an overall grassland vegetation cover of 57% of the country by 2025[6] and 60% by 2035[8] (compared to 50% in 2020). Additionally, the Grassland Ecological Protection Subsidies and Incentive Policies[38] continue to encourage practices such as pasture closure and balancing cropland and pasture through subsidies.

3.6 Wetlands

While wetlands have been recognized as an LMT in China, specific policies aimed at enhancing wetland carbon sequestration have not yet been launched. However, wetland protection objectives have been prominently featured in China's 14th Five-Year Plan[5], the Outline of the 14th Five-Year Forestry and Grassland Protection Plan[6], the National Wetland Conservation Plan (2022–30)[39], and the National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems[8]. These plans aim to increase the wetland protection rate to 55% by 2025[5,6,39] and 60% by 2035[8]. These initiatives underscore China's commitment to wetland conservation and restoration, despite the absence of specific carbon sequestration policies for wetlands. Mangroves have not been considered in this paper, but they are mentioned in the CCER scheme.

3.7 Other relevant areas

Policies that do not exclusively fall under one of the discussed land use categories, such as those related to water and soil conservation, can also contribute to reducing emissions and increasing carbon sequestration within land-based ecosystems. The National Soil and Water Conservation Plan[40], with its clear objectives, is an example. This plan sets a target of increasing the water and soil erosion control area by an additional 940 000 square kilometres (km^2) (94 million ha) nationwide by 2030. Moreover, the recently issued opinion on Soil and Water Conservation[41] further underscores the importance of these efforts, setting the objectives of the national soil and water conservation area that meets erosion control standards at a level of 73% of the total erosion-prone area of 1.445 million km^2 (144.5 million ha) by 2025 and 75% by 2035.

3.8 China Certified Emission Reduction (CCER) scheme

In March 2017, the National Development and Reform Commission ceased the issuance of approvals for new projects in the CCER scheme. Only active projects were allowed to proceed as planned. On 24 October 2023, the Ministry of Ecology and Environment introduced guidelines[42] to regulate the design, implementation, approval, emission reduction accounting, and verification of nationwide voluntary greenhouse gas reduction projects, thus relaunching the trial scheme. The new CCER methodology includes carbon sequestration through afforestation and mangrove expansion.

Table 3. Overview of the integration of LMTs in China's policy landscape, with corresponding policy numbers as used in the text and Table 2

	LMT	Policy status				Implementation initiatives and projects	CCER
		Recognition[a]	Dedicated national plan[b]	Targets affecting carbon sequestration[c]	In NDC		
Forestry	**Afforestation**	✓ 1	✓ 2, 6, 7, 8	Direct	✓	✓ 9, 10	✓
	Forest management	✓ 1	✓ 2, 12	Direct	✓	✓ 13	–
	Forest protection and restoration	✓ 1	✓ 8	Indirect		✓ 15, 16, 17, 18	–
Agriculture	**Black soil protection**	✓ 19	✓ 18, 19, 20	Indirect	–		–
	Organic fertilizer	✓ 19	✓ 25, 26, 27	Indirect	–		
	Comprehensive straw utilization	✓ 19	✓ 27, 28, 29, 30	Indirect	–		
	Rice cultivation	✓ 32	–	Indirect	–	✓ 32	
Agroforestry	**Agroforestry**	–	✓ 33	Indirect	–		–
Biochar	**Biochar**	✓ 31	–	Indirect	–		–
Grasslands	**Grasslands restoration**	✓ 1	✓ 4, 11	Indirect	–	✓ 35	
Wetlands	**Wetlands restoration**	✓ 1	✓ 4, 11, 36	Indirect	–		[d]
Soil	**Water and soil conservation**	–	✓ 37, 38	Indirect	–	–	–

Source: authors' own

Note:
[a] Recognition: is the LMT mentioned in the context of its carbon sequestration potential?
[b] Dedicated National Plan: is there a policy that sets quantitative time-specific targets for the LMT?
[c] Targets affecting carbon sequestration: are the indicators for the set targets directly related to carbon sequestration (e.g. increase carbon stock in forests by x%) or indirectly related (e.g. restore degraded wetlands by x%)?
[d] The CCER includes mangroves, but mangroves were not considered in this paper.

4. Perspectives from experts

We conducted 12 expert interviews to corroborate the insights gained from the policy analysis and to obtain a more thorough understanding of the role of land-based climate mitigation in China's climate actions, as well as the current development status and future potential of different land-based climate change mitigation technologies and practices in China. Interviews were conducted in Mandarin. The interview guide that was used for the semi-structured interviews can be found in Annex II.

Table 4 provides an overview of the interviewees' profiles in terms of sector and LMT expertise. Numbers between brackets in this section refer to interviewees, also noted in Table 4.

Based on expert input, we conducted an assessment of the implementation scale, enablers and barriers for the future development of each LMT (see Table 5).

Table 4. Expert profiles, with corresponding numbers for identification in the text

Expert elicitation: respondent profile		NGO	Research	International organization
Agriculture	Rice cultivation		2, 5	1
	Reduced tillage	3	2, 5	1, 7
	Integrated soil fertility management		2, 5	
	Organic agriculture		2, 5	1, 7
	Manure management		4	
Forestry	Afforestation/reforestation	3	10, 11, 12	9
	Forest management	3	10, 12	
	Forest restoration		12	
Agroforestry			8	1, 7, 9
Biochar			2, 4, 5, 6	1
Bioenergy with carbon capture and storage (BECCS)			6	
Wetlands management		3		
Grasslands management		3		1

Source: Authors' own

4.1 Forestry

Afforestation, up until now the main focus of land-based climate mitigation in China, is slowing down, as the country is reaching limitations in terms of suitable and available area (experts 3 and 10). Simply increasing forest cover can reduce arable land, potentially leading to food security issues and affecting the livelihoods of local residents (expert 9). Prior afforestation in physically challenging areas has also produced forests in which trees do not grow well, and where forests exert pressure on groundwater levels (expert 3). The choice of tree species is an important factor for carbon sequestration, but other impacts should also be considered, as monoculture tree planting can negatively impact biodiversity (expert 9).

The focus is now shifting towards better management of existing forests, rather than expanding forest area that is already sufficient for meeting China's 2050 forestry goals (experts 3, 10). There is a concern about how to sustain forestry's carbon sequestration capacity once it reaches its maximum potential after China achieves carbon neutrality in 2060 (expert 12).

Forming unified forest management standards at the national level is proving to be challenging, and provinces are currently working on provincial level plans (expert 3). Forest management

options, however, are limited, and they mainly consist of protection measures and planning the planting and harvesting (expert 7). When successful, forestry initiatives have the potential to improve the environment, build resilience against natural disasters, and improve the quality of life and income of local residents (expert 10).

4.2 Agriculture

Agricultural land has significant carbon sequestration potential (experts 2, 3, 5), which can at the same time deliver productivity benefits (experts 2, 5).

The agriculture sector contributes to a relatively small part of China's total greenhouse gas emissions (expert 2); "low-carbon agriculture" has not been a focus area, which is demonstrated by the delay of the Ministry of Agriculture's emission reduction plan, released a year after carbon reduction plans in other sectors (expert 7). Achieving zero emissions in agriculture is challenging, and there is currently no dedicated target for peaking emissions or achieving emission neutrality in the sector (expert 1).

The emphasis in the sector is on offsetting emissions by harnessing agriculture's carbon sequestration potential (expert 1). As a result, a significant contribution of agriculture to China's climate ambitions is likely to take place only around 2060 (expert 2).

China's agricultural focus on food security (experts 1, 2, 3, 4) is not going to change in the short term (expert 2). Therefore, measures such as organic agriculture that could negatively impact productivity are not being promoted for scaling widely (expert 2).

Other elements impacting the uptake of practices and technologies are the impacts on labour intensity and costs. Organic agriculture and reduced tillage can result in more work, a need for more advanced practices, and higher costs for farmers, and as such, these practices are not easily scalable (expert 2).

In comparison to the forestry and grassland sectors, where scaling solutions are more readily available, agriculture has the disadvantage of being decentralized over relatively small areas of land owned by smallholders (expert 3). Scaling new practices and technologies among farmers is difficult and requires the right amount of promotion and the right level of technological readiness (expert 2).

Agriculture requires subsidies and support; however, precise targeting and avoiding dependency on subsidies are crucial (expert 2). Furthermore, farmers often have a limited understanding of carbon emissions reduction, but their support is central to implementation (experts 1, 7). Previous attempts at collaboration between scientists, agriculture promotion centres, and farmers have not led to successful dissemination of practices (expert 5). Therefore, research is needed on how to incentivize farmers efficiently through policies with adequate subsidy strategies and support systems with training and technical assistance in place (experts 2, 5, 7).

Organic agriculture and soil management

Synthetic fertilizers are a large source of nitrous oxide emissions due to overapplication (expert 5). Alternatives such as organic agriculture and integrated soil fertility management can mitigate these emissions, while also offering carbon sequestration benefits (expert 2).

Green manure crops and legume cultivation during winter can aid in nitrogen fixation and soil enrichment (expert 5). The precise carbon sequestration effects of these practices, however, are uncertain due to the issues around the stability of carbon stored in soil (expert 7). Furthermore, carbon sequestration benefits in this case are confined to drylands, whereas under wet conditions such as in rice paddies, adding organic materials can result in increased methane emissions (expert 2, 5).

Increasing the soil organic carbon content in the short term would require significant material inputs and is labour intensive (expert 7).

Organic agriculture currently has limited market recognition and is not being promoted for implementation at scale (expert 7). Scaling organic fertilizers, which come at a higher cost, would require government subsidies (expert 1). The key lies in precision fertilization, which combines organic and synthetic fertilizers based on soil types, and better fertilization practices, which would offer significant emission reductions and a substantial potential for widespread adoption (experts 2, 5).

Conservation tillage

Conservation tillage and its variants offer rather limited potential for carbon sequestration, and such practices are not applicable to all crop types, production systems, and environments (experts 1, 2, 5). In rice paddies, ploughing can reduce methane emissions; returning crop residues to the fields can increase methane emissions (expert 5). On the other hand, conservation tillage is mandatory in China's northeast black soil region, where straw is returned to the fields to increase the soil organic content and avoid emissions (experts 1, 2, 5).

Special measures, such as "no-till" practices and covering soils that contain high organic carbon, have been in place since the 1990s to prevent wind erosion (experts 2, 5). Controlling soil erosion can help reducing carbon emissions, which can be significant due to the vast area affected every year (expert 7).

The carbon sequestration capacity of China's black soil needs to be enhanced effectively, an issue that remains unaddressed. The current approach of burying straw into the soil manually is not cost-effective (experts 4). Furthermore, if not properly implemented, no-till farming can lead to yield losses and issues with soil and water conservation (expert 7).

Adequate legislation for the protection of black soil is essential for its future conservation (expert 6). Where supportive policies and a strong government push are in place, such as in the case for the comprehensive use of straw, there is a significant uptake by farmers of a practice: currently about 50% of the agricultural sector practices "straw returning", 40% has other applications for the straw, and only 10% does not manage residual straw (expert 2).

Also essential is further research, given that the effectiveness of returning straw to the fields varies in different areas. Determining the optimal amount of straw to be returned is still challenging (expert 1).

Rice management

In China's southwest region in particular, paddy rice is a large source of methane emissions due to the flooding of the fields during extended periods (experts 2, 5). Controlling the soil moisture content and alternating between flooded and dry conditions are management practices that can significantly reduce emissions from rice cultivation (experts 2, 5). The scaling potential of the alternative wetting and drying technique is limited by the technical skills and labour it requires (expert 5). New rice varieties are also being bred that are drought resistant, water-saving, resource efficient, and less emission intensive (experts 1, 5). Optimizing fertilizer application is also important and various methods, including the application of wheat straw and biochar, are being tested (expert 2). Dry-seeded rice is currently not commonly applied in China (expert 4). Adequate policy support, especially during the pilot phase, is essential for widespread implementation of these emission reducing practices (expert 5).

4.3 Agroforestry

Agroforestry systems play a role in promoting biodiversity, conserving water and soil, storing carbon, and reducing emissions. Emission reductions can be achieved by substituting specific commodities in the value chain with alternatives that have lower emission intensities, contributing to emission reductions both locally and throughout the value chain (expert 8). However, estimating the carbon sequestration benefits of agroforestry is challenging, due to the multitude of variables for trees, soils, crops and more, with each variable having different impacts and requiring tailored methodologies (expert 7). This complexity makes it difficult to integrate agroforestry in policies and schemes at the national level (expert 7).

Due to the distinction between forestry and agriculture in China's policies, agroforestry has not been fully integrated in either sector (expert 8). Furthermore, terminology used to describe these practices may vary by sector, making it more difficult to look at agroforestry as a single approach (expert 7). The larger applications of agroforestry in China are protective forest belts around farmlands (expert 8). Many agroforestry initiatives are driven from the grassroots level, and demonstration areas exist in various parts of the country (expert 7).

4.4 Biochar

Biochar offers significant carbon sequestration potential, especially among potential agricultural interventions (expert 2). Besides sequestering carbon, biochar can contribute to energy production, thus replacing fossil fuels, and to fertilizer production, replacing synthetic fertilizers (expert 4).

Livestock manure could be an ideal source for biochar. Left unprocessed, it is a large source of emissions and is difficult to manage (experts 4, 5). Its direct application to fields is not recommended due to the high emissions it entails (experts 4, 5) and excessive levels of heavy metals and antibiotics (expert 4). Composting manure before use as fertilizer can reduce emissions (expert 5), but turning it into carbonized fertilizer – biochar – can help mitigate both emissions and risks (expert 4).

Crop straw is another important potential feedstock for the production of biochar (expert 4). Bottlenecks in scaling certain practices and technologies in the foreseeable future may be the limited availability of organic materials (expert 2).

The Ministry of Agriculture supports the development of biochar for carbon sequestration and manure management (experts 4, 6). It also encourages the private sector to take part in the development of the biochar value chain (expert 4), and many companies are starting to explore its potential (expert 6).

Despite being a popular solution promoted by some researchers (expert 5), the widespread adoption of biochar remains hampered by a variety of factors (experts 1, 2, 4, 5, 6). In addition to the lack of clear policies for implementation (experts 1, 5, 6), a profitable business model is missing (1, 2), and there are associated high costs and the need for long-term return on investment (experts 1, 4, 5, 6). From a production perspective, the spatial distribution of biochar production and application (experts 4, 6) and the time and labour required to collect residual straw (expert 5) are also drawbacks. Farmers are reluctant to adopt new practices that combine biochar and organic fertilizer or learn the different practices required based on local soil types (expert 6); plus, the promotion of returning straw to the field creates competition for the biomass (expert 5). The cross-cutting nature of biochar production and use with different sectors, such as energy, also requires it to be integrated in broader energy and biomass strategies (expert 4).

4.5 Grasslands

Grasslands have significant carbon sequestration potential but have not yet received a lot of attention in this regard. This is despite the fact that interventions to maximize grassland sequestration potential are generally more straightforward and cost-effective than the mitigation practices and technologies in other sectors, such as forestry and agriculture (expert 3).

China has vast areas of grasslands, some well-protected, others degraded (experts 1, 3). Where they are degraded, this is mainly due to overgrazing (expert 3). Existing policies and subsidies promote grassland ecological restoration, including measures for rotational grazing, seasonal grazing bans, grassland reseeding, and enhancing biomass production. Artificial grasslands are also being promoted to reduce pressure on natural grasslands (expert 1).

Grassland policies need objective evaluation, and better methodology is needed for monitoring carbon sequestration. Some incentive policies have faced criticism for being "one size fits all", proving inadequate to deal with unique characteristics of different grasslands (expert 1).

4.6 Wetlands

The focus of current policies on wetlands is on protecting their ecological functions, rather than increasing their carbon stock. Policies on wetlands are not as clear as those for forestry and grasslands, and their carbon sequestration potential is estimated to be relatively low (expert 3).

4.7 China Certified Emission Reduction (CCER) scheme

The CCER scheme has the potential to stimulate emission reduction projects in the land sectors by acting as a source of funding (experts 3, 4, 10), especially in areas where government funding may be lacking (expert 3). The current methodologies for meeting the standard of CCER projects are stringent, and the methods need to be simplified to allow for implementation at scale (experts 3, 10). Practitioners also need to receive the appropriate capacity building to be able to implement valid projects (expert 3).

The CCER methodology and implementation have been focused on the forestry sector but are also encouraged in other land sectors (experts 3, 10). The Ministry of Ecology and Environment will consider introducing grasslands into the scheme by the end of 2023, but better methodology on carbon sequestration in grasslands is needed (expert 1).

In the agriculture sector, CCER can help practitioners realize the potential of agriculture in mitigating climate change, while allowing for an income stream from carbon sequestration (expert 2). In agriculture specifically, it is difficult to estimate carbon sequestration with a high level of certainty (experts 3, 9), which has led to rice cultivation currently being excluded from the CCER scheme (expert 3). There is a need for better specialized methodology to be developed to allow for emission reduction and carbon sequestration projects in the agriculture sector (experts 1, 5, 7).

Furthermore, the system is likely to be more attractive to large operations rather than smallholder farmers, since they often hold greater carbon sequestration potential and can shoulder the high costs related to the technical monitoring, reporting and verification requirements (experts 2, 4, 5). One option would be for smallholders to combine their activities into a joint project, in order to reach the scale and resources required (expert 4). Agriculture projects aiming for CCERs should aim at keeping project costs reasonable and avoiding impacting food production (expert 2). Besides carbon sequestration, projects should also focus on yield enhancement and soil health improvement, which are current priorities in the sector (experts 2, 3), as well as farmers' incomes (expert 4).

4.8 China's regional impact

China exercises strict control on international cooperation and typically only engages when there is a broad international cooperation framework in place (expert 10). Still, initiatives exist related to crop varieties, new technologies and practices, and farmers' livelihoods (experts 2, 4).

For example, a UK–China project is under way to enhance India's biomass carbon industry, by promoting application and industrialization of biomass fuels and fertilizers through technical assistance (expert 2). Other examples include projects related to biochar: a Chinese university is assisting ASEAN countries and the Asian Development Bank with the application of biochar by providing demonstrations and training, and Chinese companies processing biochar are looking at ASEAN markets for agricultural residues, such as durian waste from Malaysia and rice husk from Myanmar (expert 4).

On agroforestry, China collaborates with countries in Southeast Asia, as well as in Africa (expert 8).

In alignment with China's Belt and Road Initiative, collaboration on advancing technologies in areas such as efficient nutrient and water utilization is expected to increase in the future (expert 2).

Table 5. Overview of LMT-specific enablers and barriers mentioned by the interviewees

	LMT	Implementation Scale	Enablers	Barriers
Forestry	**Afforestation**	National, Three-North Belts	Long-term political commitment Enter carbon market through CCER Co-benefits: improve environment, resilience against disasters, and livelihoods	Limited available area for expansion
	Forest management	National, Sichuan, Inner Mongolia, Yunnan	Long-term political commitment Co-benefits: improve environment, resilience against disasters, and livelihoods	Limited options Lacking technical guidance
	Forest restoration	Designated Ecological Zones	Co-benefits: improve environment, resilience against disasters, and livelihoods	
Agriculture	**Conservation tillage**	Prevalent in Northeastern region	Mandatory in the northeastern region	Increased cost and labour intensity Benefits depend on soil, crop type and production system Potential yield loss
	Organic fertilizer	Applied to high-value crops	Government subsidies Modern technology application Consumer and business preference for organic	Increased input cost and labour intensity Potential yield loss Uncertainty on permanence of soil organic carbon
	Comprehensive straw utilization	National, most widespread practice	Government promotion Increasing mechanization	Lacking method for calculating sequestered carbon Increased labour intensity Lack of lightweight equipment
	Rice cultivation	Mainly in the south	Increasing modern technology for irrigation and dry-seeded rice	Knowledge and technical skills requirements Lacking method for calculating sequestered carbon Current lack of mechanization in water management
Agroforestry		National	Economic benefits Increasing interest in travelling in villages Existing bottom-up initiatives Co-benefits: improve biodiversity, water, soil, impact value chain	Unclear carbon sequestration potential due to lack of standardization
Biochar		National	Scientific evidence on biochar as fertilizer and on carbon sequestration Supported by the government Co-benefits: energy production, fertilization	Lacking method for calculating sequestered carbon Lack of profitable commercial model Limited feedstock High-cost and long-term investment Labour intensity Reluctance of farmers to change practices Variable local effects
Grasslands	**Grasslands restoration**	National	Government subsidies for rotational grazing, temporary grazing bans, grassland reseeding and biomass production Large area, even more than forestland	Lacking method for calculating sequestered carbon Lack of tailored practice for different kinds of grassland
Wetlands	**Wetlands restoration**	National	International organization projects	Unclear status Lacking method for calculating sequestered carbon

5. Discussion and conclusions

Due to its land area size and environmental conditions, China is one of the countries with the highest climate change mitigation potential through land-based mitigation technologies and practices. Despite this potential and the wide range of co-benefits LMTs have to offer, China's climate change mitigation efforts have thus far focused on other sectors such as energy and industry, suggesting a missed opportunity. Another measure of potential for increased carbon sequestration under improved practices comes from research that has shown that different types of land in China that have historically been depleted still carry the traces of prior disturbances in the form of lower carbon stocks than similar areas elsewhere.

Current frameworks could harness this potential over the next few years: the importance of healthy ecosystems, in particular in light of their carbon sequestration abilities, has been officially recognized in China's Policies and Actions for Addressing Climate Change, and based on the amount of recently published documents and launched initiatives, more emphasis can be expected on carbon sequestration ecosystem functions. This emphasis is expected to be particularly pronounced beyond 2030, after China plans to peak in its carbon emissions and moves towards climate neutrality before 2060, considering the two-phased climate targets outlined by the government.

However, the current dispersed nature of policies deserves attention. Land use–specific plans and roadmaps are scattered across the different land sectors, and the number of dedicated documents, as well as the level of detail and commitment, varies starkly between different land uses and LMTs. Among land use and ecosystem types, forestry has received the most attention for its contribution to carbon sequestration through afforestation, forest management and forest restoration. This is reflected in the amount of policy documents, including China's NDC, presenting plans, targets and indicators for the forestry sector. Due to large-scale afforestation, reforestation and restoration initiatives over the past decades – which in many cases were not mainly aiming for carbon sequestration benefits – forestland has become a major carbon sink in China. In 2020, this forest carbon sink nearly compensated for the country's entire agricultural, forestry and other land use (AFOLU) emissions. However, the relevance of other land sectors in carbon sequestration is likely to increase as the land available for wider forest expansion as well as the carbon sequestration capacity of established forests becomes saturated.

In these scenarios, agricultural emissions in particular eventually will need to decrease. However, because food security is the top priority for China's agricultural sector, any changes in agricultural practices that risk negatively affecting productivity have not been promoted, including organic practices in particular, which increase sequestration, but can also increase costs and dampen productivity. Nevertheless, some policies that have targeted other benefits have effectively enhanced carbon sequestration in agricultural lands. An example of such indirect effects is the strong policy push for crop residue management, aimed at combating soil erosion and improving soil quality, that has led to an increase in soil organic carbon. The 2022 launch of the Agriculture and Rural Areas Emission Reduction and Carbon Sequestration Implementation Plan[19] demonstrates the intention to address emissions and sequestration potential in the agricultural sector, but this is a recent development and detailed indicators and targets on carbon sequestration are yet to be devised.

Beyond forests and agriculture, some other land use types such as grasslands and wetlands that seemingly have small potential impacts in comparison can make an important difference in carbon sequestration if managed correctly. We expect these will become more important as other sinks and LMTs reach their full capacity. Industrial applications such as biochar and bioenergy with carbon capture and storage (BECCS), although generally recognized for their carbon sequestration potential, do not yet seem to be present in the Chinese climate change mitigation policy landscape.

More focus on emissions and sequestration potential from the land sectors will be necessary on China's decarbonization and net-zero journey. This will entail improving policy frameworks, methodologies, incentives schemes, and implementation practices across land sectors. The relaunch of the CCER scheme in 2023 is an example of an instrument that may further promote financing and implementation of LMTs, even though it is currently limited to the forestry sector in its trial form.

Overall, China's national targets regarding land are considered ambitious, feasible and likely to be achieved by the experts we interviewed (experts 2, 3, 4, 5, 10), and these targets are important to fulfil China's commitments to the Paris Agreement (experts 3, 10). The commitments outlined in the NDC are considered the most effective and most likely to be achieved due to their monitoring through progress reports (expert 3).

Land use planning is strictly controlled in China, meaning that certain issues related to competition between different types of land use such as deforestation due to encroaching agricultural land are largely absent (expert 3). Nevertheless, some major challenges still inhibit the full realization of carbon sequestration from LMTs. Informed by our interviews with experts, we make the following observations in relation to challenges and needs:

1. Carbon sequestration is a complex process with multiple climate, environmental and economic factors involved, making it challenging to develop the standardized methodologies needed for policy and implementation (expert 8).

2. A comprehensive roadmap to support the achievement of the country's land use goals, as well as mechanisms that provide the corresponding funding, are still lacking (experts 3, 5). The fact that different ministries are involved, each in their respective sector, means that policies can be siloed leaving many synergies unaddressed. There needs to be a systemic perspective on emission reductions, since they are intertwined with land use and food production (expert 9).

3. As responsibilities are spread across various government departments, access to updated and comprehensive harmonized data can be difficult (expert 5).

4. Successful LMT implementation will require distinguishing between the numerical targets to be achieved and the quality of the results, as usage rates of agricultural waste or the amount of land under a certain management type do not automatically translate into actual levels of carbon sequestration or other variables (experts 2, 4, 7).

5. As afforestation reaches saturation in terms of suitable available land and the focus shifts to forest management (experts 3, 10), other land sectors such as agriculture and grasslands need to be considered for their potential role in carbon sequestration; dedicated incentives may be required to encourage action (expert 3).

6. More comprehensive indicators should be created to include, for example, farmland quality, economic benefits and carbon sequestration (experts 2, 4). These metrics are related to the importance of going beyond reaching certain adoption levels and to expanding the focus to include other land sectors.

7. Even though the policy boundary between agriculture and forestry may be clear, the everyday land management practices of farmers do not necessarily align with these boundaries, a fact that is often neglected in policy (expert 8).

8. To implement changes in the agricultural sector, it is crucial that farmers are on board. Currently, however, they often have limited knowledge of the potential for emission reductions or carbon sequestration, so training and technical support, as well as adequate subsidy strategies incentivizing climate change mitigation on agriculture land, are needed (experts 1, 2, 5, 7).

9. All measures should be tailored to local conditions to allow for optimization of practices depending on the local systems, environment, geographical conditions and infrastructure (experts 1, 2, 7, 9). Localized case studies, which are currently lacking, can provide information for these scenarios.

References

Note: The policies identified and analysed during the policy review are listed in Table 2 and in Annex I, and they are not cited in the references below.

Chen, M., Forsell, N., Yu, S., Chang, J., Wang, X., Mosnier, A., & Cui, Y. (2023). *Modelling Greenhouse Gas Fluxes from China's Agriculture, Forestry and Land Use Sector: Gaps and recommendations*. The Food and Land Use Coalition.

Chen, M., Hu, M., Yang, L., & Ma, Z. (2022). *The Agri-Food System and Carbon Neutrality: An Analysis of Agriculture and Food-Related Greenhouse Gas Emissions Mitigation Pathways in China* [Working Paper]. innovative Green Development Program (iGDP).

Climate Watch. (2021). Historical emissions data, retrieved 3 January 3 2024, from https://www.climatewatchdata.org/data-explorer/historical-emissions?historical-emissions-data-sources=climate-watch&historical-emissions-end_year=2020&historical-emissions-gases=all-ghg&historical-emissions-regions=CHN&historical-emissions-sectors=All%20Selected&historical-emissions-start_year=2020&page=1&sort_col=data_source&sort_dir=DESC

Ding, H., Mosnier, A., Douzal, C., Bai, Z., Zhao, H., Cook, S., & Fan, S. (2023). *Tapping the Emissions Reduction Potential of China's Food and Land Use Systems to Achieve Carbon Neutrality*. The Food and Land Use Coalition.

Fang, J., Yu, G., Liu, L., Hu, S., & Chapin, F. S. (2018). Climate change, human impacts, and carbon sequestration in China. *Proceedings of the National Academy of Sciences*, *115*(16), 4015–4020. https://doi.org/10.1073/pnas.1700304115

FAOSTAT. (2021). Data retrieved 3 January 2024, from https://www.fao.org/faostat/en/#data/GT

Lu, N., Tian, H., Fu, B., Yu, H., Piao, S., Chen, S., Li, Y., Li, X., Wang, M., Li, Z., Zhang, L., Ciais, P., & Smith, P. (2022). Biophysical and economic constraints on China's natural climate solutions. *Nature Climate Change*, *12*(9), 847–853. https://doi.org/10.1038/s41558-022-01432-3

Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A., Doelman, J., Emmet Booth, J., Engelmann, J., Fricko, O., Frischmann, C., Funk, J., Grassi, G., Griscom, B., Havlik, P., Hanssen, S., Humpenöder, F., Landholm, D., … Lawrence, D. (2021). Land based measures to mitigate climate change: Potential and feasibility by country. *Global Change Biology*, *27*(23), 6025–6058. https://doi.org/10.1111/gcb.15873

Tang, X., Zhao, X., Bai, Y., Tang, Z., Wang, W., Zhao, Y., Wan, H., Xie, Z., Shi, X., Wu, B., Wang, G., Yan, J., Ma, K., Du, S., Li, S., Han, S., Ma, Y., Hu, H., He, N., … Zhou, G. (2018). Carbon pools in China's terrestrial ecosystems: new estimates based on an intensive field survey. *Proceedings of the National Academy of Sciences*, *115*(16), 4021–4026. https://doi.org/10.1073/pnas.1700291115

Annexes

Annex I: Policy Table

Document information				Policy scope				Targets	
Document name English, Chinese Click link to go to source	**Name of organization, ministry, etc.**	**Type of document**	**Year published**	**LMT**	**Temporal scope**	**Geographic scope [Local, regional (in-country), national]**	**Year**	**Quantitative target**	**Qualitative target**
1 China's Policies and Actions for Addressing Climate Change 中国应对气候变化的政策与行动	The State Council	Action Policy	2021	Afforestation Forestry Protection Forestry Management Wetland Managament Grassland Management Green Agriculture		National			Continuously enhance ecological carbon sequestration capacity.Coordinate the comprehensive management of mountains, waters, forests, farmlands, lakes, grasslands, and sands, vigorously promote large-scale national land greening initiatives, maintain ongoing projects such as the Three-North Shelterbelt Program, Yangtze River protection, Northeast black soil conservation, high-standard farmland construction, wetland protection and restoration, returning farmland to forests and grasslands, grassland ecological restoration, control of dust and sand sources in Beijing and Tianjin, and comprehensive management of desertification and rocky desertification. Steadily advance urban and rural greening, scientifically manage and nurture forests, precisely improve forest quality, actively develop biomass energy, strengthen the protection of forest and grassland resources, continuously increase the total resources of forests and grasslands, and consolidate the enhancement of carbon sequestration capacity in forest, grassland, and wetland ecosystems
2 China's implementation of NDC and progress report(2022) /中国落实国家自主贡献目标进展报告(2022)	Ministry of Ecology and Environment	Planning Policy	2022	Afforestation/Reforestation	2022-2030	National	2030	1. Increase 6 billion m3 forest stock volume by 2030 compared to 2005 levels. 2. Plant, protect, and restore 70 billion trees within 10 years	
3 China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy.中国本世纪中叶长期温室气体低排放发展战略。	The State Council	Planning Policy	2021	Afforestation/Reforestation	2021-2030	National	2030	1. forest coverage rate will reach about 25% 2. forest stock volume will increase 6 billion cubic meters over 2005 level	1. Enhance carbon sink of ecosystems 2. Efforts will be made to implement major projects to protect and restore important ecosystems, and carry out integrated protection and restoration of mountains, rivers, forests, farmland, lakes, grasslands, and sand.
4 China's Action Plan for Reaching Peak Carbon Emissions by 2030. 中国2030年前碳达峰行动方案	The State Council	Planning Policy	2021	Afforestation/Reforestation Low carbon agriculture Reduce chemical fertilizer Black soil protection Cropland management	2021-2030	National	2030	1. 25 % forest coverage rate 2. 19 billion cubic meters in forest stock volume shall be reached	Consolidation and Improvement of Carbon Sequestration Capacity include the tasks such as: consolidating the role of ecosystem carbon sequestration, improving the capacity of ecosystem carbon sequestration, strengthen the basic support of ecosystem carbon sequestration, and promote agricultural and rural carbon emission reduction and carbon sequestration.
5 China's 14th 5-year plan (2021-2025)/ 十四五规划（2021-2025）	The State Council	Planning Policy	2021	Afforestation/Reforestation Grassland management Wetland management	2021-2025	National	2025	1. Increase the wetland protection rate to 55% (52% in 2020) 2. increase forest cover to 24.1% (2020 goal was 23.2%) 3. 8 major projects in different ecological zones	
6 Outline of the "14th Five-Year" Forestry and Grassland Protection and Development Plan."十四五"林业草原保护发展规划纲要.	National Forest and Grass Bureau	Planning Policy	2021	Afforestation/Reforestation Grassland management Wetland management	2021-2025	National	2025	1. the forest coverage rate will reach 24.1%, 2. the forest volume will reach 19 billion cubic meters 3. the comprehensive vegetation coverage of grassland will reach 57% 4. the wetland protection rate will reach 55% 5. and the area of nature reserves dominated by national parks will account for more than 18% of the land area	

#	Policy	Agency	Type	Year	Focus	Period	Level	Target Year	Targets	
7	National forest management plan (2016-2050)/ 全国森林经营规划 (2016-2050 年)	National Forest and Grass Bureau	Planning Policy	2016	Afforestation/Reforestation	2016-2050	National	2050	1. The national forest coverage rate is stable at more than 26% 2. The forest stock volume reaches more than 23 billion cubic meters. 3. The stock volume of arbor forest per hectare reaches more than 121 cubic meters 4. The average annual growth volume of arbor forest per hectare reaches more than 5.2 cubic meters 5. The stock volume of arbor forest per hectare in the forest management demonstration area reaches more than 260 cubic meters, and the average annual growth volume of arbor forest per hectare reaches more than 8.5 cubic meters" 6. The total carbon storage of forest reaches more than 13 billion tons	
8	National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems (2021-2035) 全国重要生态系统保护和修复重大工程总体规划（2021—2035 年）	The State Council	Master Plan	2021	Forest Restoration Wetland managament Grassland management	2021-2035	National	2035	1. The national forest coverage rate reach to 26% 2. forest volume will reach 21 billion cubic meters 3. Grassland comprehensive vegetation coverage reaches 60% 4. wetland protection rate reaches 60% 5. the natural forest area will remain stable at about 200 million hectares	
9	General Plan for the Three-North Shelterbelt System Construction Project 三北防护林体系建设工程总体规划	The Three-North Shelterbelt Construction Bureau of the State Forestry and Grassland Administration	Project Plan	2022	**Afforestation**			2050	The Three-North Project plans to afforest 35.083 million hectares (including the converted area of forest belts and grids), of which 26.371 million hectares will be afforested through artificial planting, accounting for 75.1% of the total task; aerial seeding afforestation will cover 1.114 million hectares, making up 3.2%; afforestation through closing off mountains and sand areas will encompass 7.598 million hectares, constituting 21.7%. Additionally, 5.24 billion trees will be planted around the periphery	
10	14th 5-year plan on village greening program/ 十四五"乡村绿化美化行动方案	National Forest and Grass Bureau Ministry of Agriculture and Rural Affairs Ministry of Natural Resources Ministry of Water Resources	Program actions	2022	Afforestation	2022-2025	National (villages)	2025	1.The national average village green coverage rate will reach 32% 2.more than 1.5 billion trees will be planted "around" the villages	
11	Fujian Province Land Greening Plan 福建省国土绿化规划	Fujian Provincial Greening Committee	Planning Policy	2022	Afforestation/Reforestation	2020-2030	Provincial	2025	1. The forest coverage rate increased by 0.12 percentage points, reaching to 65.24 in 2025compared to 65.12 in 2020 2. The forest stock volume per unit area (cubic meters per hectare) increase to 122 in 2025 from 121.64 in 2020	
								2030	1. The forest coverage rate will increase by 0.19 percentage points reaching to 65.31 compared o 65.12 in 2020 2. The forest stock volume per unit area (cubic meters per hectare) continue to increase from 2025 to 2030	

12	National Sustainable Forest Management Pilot Implementation Plan (2023-2025) 全国森林可持续经营试点实施方案（2023—2025年）	National Forest and Grass Bureau	implementation plan	2023	Forest management	2023-2025	National	2025	310 forest management units are selected by each province, focusing on state-owned forests, taking into account collective forests, and considering artificial forests, commercial forests, natural forests, and public welfare forests in accordance with the principle of first easy before difficult, scientifically carry out sustainable forest management, and strengthen young and middle-aged forests. Forest tending, exploring models, innovating mechanisms, building a number of demonstration model forests, forming a number of typical experiences and institutional measures that can be replicated and promoted, and creating advanced demonstration models.	Exploring the business model of state-owned forests to fix carbon and increase sinks
13	Sichuan Province's Work Plan for Promoting National Sustainable Forest Management Pilot Work Plan (2023-2025) 四川省推进国家森林可持续经营试点工作方案（2023—2025年）	Sichuan Forestry and Grassland Bureau	Action plan	2023	Forest management	2023-2025	Provincial		Sichuan is one of the provinces with the richest plantation resources in the country, but the volume of wood that can be produced per mu of plantation forest is only 2.89 cubic meters, which is 72.2% of the national average level. There are 75 million mu of plantation forests that urgently need to be cultivated and managed.	The plan focuses on the cultivation of young and middle-aged forests with a growth time of less than 20 years, and scientifically reduces forest density and improves forest quality through methods such as harvesting small ones and leaving large ones, picking poor ones and retaining good ones, and harvesting dense ones and leaving thin ones.
14	Ecosystem protection and repairment plan(2021-2035) 生态保护和修复支撑体系重大工程 建设规划(2021-2035 年)	National Development and Reform Commission Ministry of Science and Technology Ministry of Natural Resources Ministry of Ecology and Environment Ministry of Water Resources Ministry of Agriculture and Rural Affairs Ministry of Emergency Management China Meteorological Administratio National Forest and Grass Bureau	Planning Policy	2021	Forest Restoration	2021-2035	National	2025	1. The damage rate of forest and grassland fires shall be controlled within 0.9‰ and 2‰ respectively, 2. The disaster rate of forestry pests shall be controlled below 8.2‰1 3. The rate of artificial rain and snow enhancement shall be increased to 12%-15%	
								2035	1. Complete 200-300 national-level scientific and technological support projects in the field of ecological protection and restoration 2. control the damage rate of forest and grassland fires within 0.8‰ and 2‰ respectively, 3. control the disaster rate of forestry pests at about 7.2‰2, 4. artificially increase the rate of rain and snow Stable at 12%-15%	
15	Northneast forestry plan(2021-2035) 东北森林带生态保护和修复重大工程 建设规划(2021—2035 年)"	National Forest and Grass Bureau National Development and Reform Commission Ministry of Natural Resources Ministry of Water Resources	Planning Policy	2021	Forest Restoration Wetland managament Grassland management	2021-2035	Regional (Northerneast)	2025	1.The forest coverage rate in the project area reached 64.8% 2.The volume per hectare reached 110.6 cubic meters	
								2035	The area of natural forests will reach 36.71 million hectares; 2.54 million hectares of natural forest reserve resources (afforestation and restoration of degraded forests) will be cultivated; 25.74 million hectares of forest tending will be completed. hectares; 190,000 hectares of degraded grassland, 280,000 hectares of desertified land and 1.92 million hectares of water and soil erosion areas wlll be newly treated and controlled; the conversion of farmland to wetlands will be carried out in a steady and orderly manner, 14,700 hectares of wetlands will be restored, and the ecological restoration of abandoned mines will be completed. The forest coverage rate in the project area will reach 66.2%, the forest stock volume will reach 4.82 billion cubic meters.	

#	Name	Institution	Type	Year	Category	Period	Region	Target year	Targets	Additional
16	Northern sand prevention belt protection and repairement plan(2021-2035)/北方防沙带生态保护和修复重大工程 建设规划 (2021—2035 年)	National Forest and Grass Bureau National Development and Reform Commission Ministry of Natural Resources Ministry of Water Resources	Planning Policy	2021	Afforestation/Reforestation Grassland management	2021-2035	Regional (North)	2025	1. The regional forest coverage rate reached about 14.9%, 2. the forest stock volume reached 580 million cubic meters 3. The grassland comprehensive vegetation coverage reached about 43.9%	
								2035	1. The regional forest coverage rate will reach about 15.5% 2. forest volume will reach 740 million cubic meters 3. grassland comprehensive vegetation coverage will reach about 45.9%	1. the area of natural forests and natural wetlands will not decrease.
17	Plan of dry land in southern mountain and hilly region (2021-2035)/ 南方丘陵山地带生态保护和修复重大工程 建设规划	National Forest and Grass Bureau National Development and Reform Commission Ministry of Natural Resources Ministry of Water Resources	Planning Policy	2021	Afforestation/Reforestation	2021-2035	Regional(South)	2025	1. The forest coverage rate reached 68.9% 2. the area of protective forests reach 110,000 hectares	
								2035	1. The forest coverage rate reached 69.3% 2. 310,000 hectares of protective forests have been established	1. The stock volume increased significantly
18	Daxiao xingan mountain forest planing(2021-2035)&14th 5-year plan on Daxiao xingan mountain/ 大小兴安岭林区生态保护与经济转型规划&"十四五"大小兴安岭林区生态保护与经济转型行动方案	National Development and Reform Commission National Forest and Grass Bureau	Planning Policy& Program actions	2021	Forest Restoration	2021-2035	Regional (Daxiao xingan mountain)	2025/ 2035		1. The quality of ecosystem in the Greater and Lesser Khingan Mountains forest area will be further improved 2. The important barriers for maintaining regional ecological security will be stable 3. The carbon sink capacity and level have been further improved
19	Agricultural and Rural Emission Reduction and Carbon Sequestration Implementation Plan/农业农村减排固碳实施方案	Ministry of Agriculture and Rural Affairs	Action plan	2022	Cropland management	2022-2030	National	2025/ 2030		1. Actions to reduce methane emissions from paddy fields 2. Actions to reduce chemical fertilizers and increase efficiency 3. Actions to enhance farmland carbon sinks
20	National high-standard farmland construction plan 全国高标准农田建设规划	Ministry of Agriculture and Rural Affairs	Action plan	2021	Biochar Water management in rice cultivation	2021-2030	National	2025	1. 1.075 billion mu of high-standard farmland to be established 2. 150 million mu of high-standard farmland will be transformed and improved. 3. secure grain production capacity exceeding 1.1 trillion jin (1.1 trillion jin would be roughly equivalent to 550 billion kilograms)	During the planning period, efforts will be concentrated on building contiguous areas that can ensure harvests during droughts and floods, save water, be efficient, and stabilize production. High-yield, eco-friendly, high-standard farmland
								2030	1. to establish 1.2 billion mu of high-standard farmland 2. 280 million mu of high-standard farmland will be transformed and improved. 3. to ensure grain production capacity exceeding 1.2 trillion jin (approximately 600 billion kilograms). 4. to construct 110 million mu (approximately 7.2 million hectares) of new efficient water-saving irrigation.	
21	Northeast Black Land Protection Planning Outline (2017-2030) 东北黑土保护规划纲要 （2017—2030年）	Ministry of Agriculture the National Development and Reform CommissionMinistry of Finance, Ministry of Land and Resources, Ministry of Environmental Protection, Ministry of Water Resources	Planning outline	2017	Black soil protection Conservation tillage and no tillage	2017-2030	Northeast	2030	1. Protected area. By 2030, the area of black soil protection will be 250 million mu in a concentrated and contiguous manner. 2. The quality of cultivated land. By 2030, the quality of cultivated land in the black soil region of Northeast China will increase by more than 1 grade (category) on average; the average content of soil organic matter will reach more than 32g/kg, an increase of more than 2g/kg	
22	Northeast Black Land Conservative Cultivation Action Plan (2020-2025) 东北黑土地保护性耕作行动计划 （2020—2025年）	Ministry of Agriculture and Rural Affairs Ministry of Finance	Action plan	2020	Black soil protection Conservation tillage and no tillage	2020-2025	Northeast	2025	Strive to implement conservation tillage to reach 140 million mu by 2025, accounting for about 70% of the total arable land in suitable areas in Northeast China	

#	Policy	Issuing Body	Type	Year	Topic	Period	Scope	Target Year	Goals	Notes
23	National Black Soil Protection Project Implementation Plan (2021-2025) 国家黑土地保护工程实施方案（2021—2025 年）	Ministry of Agriculture and Rural Affairs National Development and Reform Commission Ministry of Finance Ministry of Water Resources Ministry of Science and Technology Chinese Academy of Sciences National Forest and Grass Bureau+B66:B67	implementation plan	2021	Black soil protection Conservation tillage and no tillage	2021-2025	Northeast	2025	1. protecting 100 million mu of black land 2. constructing 50 million acres of high standard farmland 3. treating 7000 large and medium-sized erosion ditches 4. implement multiple modes of arable land conservation for 500 million mu 5. returning organic fertilizer to 100 million mu of farmland. 6. After the implementation of the plan, the quality of cultivated land will be significantly improved 7. he average organic matter content of soil will increase by more than 10%.	In terms of content, emphasis is placed on implementing measures such as soil erosion control, farmland infrastructure construction, cultivation of fertile tillage layers, and monitoring and evaluation of farmland quality.
24	Black Soil Protection Law of the People's Republic of China 中华人民共和国黑土地保护法	Standing Committee of the National People's Congress	Law	2022	**Black soil protection** **Conservation tillage and no tillage**		National			1. implement a crop rotation system that combines land use and land cultivation, and promote moderate fallow in accordance with relevant state regulations; 2. Promote conservation tillage techniques 3. Promote methods of returning to the field, such as straw mulching, crushing and deep (turning) burial, and abdominal transformation according to local conditions; 4. reduce the amount of chemical fertilizers used, encourage the application of organic fertilizers, and promote technologies such as soil biological improvement;
25	Heilongjiang province's 14th Five-Year Plan for Black Land Protection 黑龙江省"十四五"黑土地保护规划	General Office of the People's Government of Heilongjiang Province	Planning Policy	2021	Black soil protection Conservation tillage and no tillage	2021-2025	Provincial	**2025**		
26	Jilin Province Black Soil Protection Master Plan (2021-2025) 吉林省黑土地保护总体规划（2021-2025）	"General Office of the People's Government of Jilin Province"	Planning Policy	2021	**Black soil protection** **Conservation tillage and no tillage**					
27	Action Plan for Substituting Chemical Fertilizers with Organic Fertilizers for Fruit, Vegetable and Tea 开展果菜茶有机肥替代化肥行动方案	"Ministry of Agriculture (before the bureaucratic reform) "	planning policy	2017	Organic fertilizer	2017-2022	National	202o	1. By 2020, reduce the amount of chemical fertilizers used in the dominant fruit and vegetable tea production areas by more than 20%, and reduce the amount of chemical fertilizers in the fruit and vegetable tea core production areas and well-known brand production bases (parks) by more than 50%. 2. By 2020, the organic matter content of orchard soil in advantageous production areas will reach 1.2% or increase by more than 0.3 percentage points	
28	National Plan for Sustainable Agricultural Development (2015-2030) 全国农业可持续发展规划（2015-2030年）	Ministry of Agriculture (before the bureaucratic reform)	Planning Policy	2015	Afforestation/Reforestation Organic agriculture	2015-2030	National	2020	1. the forest coverage rate will reach more than 23%, The national grassland comprehensive vegetation coverage rate reached 56%. 2. achieve zero growth in the use of chemical fertilizers and pesticides	
								2030	Crop straw is fully utilized	
29	14th Five-Year Plan on National Green Agricultural Development "十四五"全国农业绿色发展规划	Ministry of Agriculture and Rural Affairs National Development and Reform Commission Ministry of Science and Technology Ministry of Natural Resources Ministry of Ecology and Environment National Forestry and Grassland Administration	Planning Policy	2021	Reduced tillage Organic agriculture Cropland management	2021-2025	National	2025	1. Cultivated land quality grade 4.58 2. The comprehensive utilization rate of straw is 86% 3. The comprehensive utilization rate of poultry manure is 85% 5. The area of degraded farmland treatment is 14 million mu 6. 100 million mu of protected and utilized black land in Northeast China	significantly enhance the ability of emission reduction and carbon sequestration.

30	Notice of the General Office of the Ministry of Agriculture and Rural Affairs on Doing a Good Job in the Comprehensive Utilization of Crop Straws in 2022 农业农村部办公厅关于做好2022年农作物秸秆综合利用工作的通知	Ministry of Agriculture and Rural Affairs	Planning policy	2022	Biochar	2022	**National**			Biochar is not identified as a approach but straw utilization aims for carbon sequestration is stated in policy
31	Guiding Opinions on Comprehensive Utilization of Bulk Solid Waste during the "14th Five-Year Plan" 关于"十四五"大宗固体废弃物综合利用的指导意见	Ministry of Agriculture and Rural Affairs and the State council and the others	Planning policy	2021	Comprehensive utilization of straw	2021-2025	National	**2025**		Adhere to the priority of agricultural use, continue to promote the use of straw as fertilizer, feed and base material, and give full play to the functions of straw cultivated land conservation and planting and breeding.
32	The Central Central State Organs on Doing a Good Job in Key Works in the "Three Rural" Fields to Ensure Realize a well-off society in an all-round way as scheduled Realize the meaning of a well-off society in an all-round way as scheduled 中央中央国家机关关于抓好"三农"领域重点工作确保如期现实全面小康	The State Council	Opinion	2020	Low carbon agriculture Reduce chemical fertilizer Comprehensive utilization of straw Black soil protection	2020-?				1. reduce chemical fertilizer in rural area 2. promote comprehensice utilization of straw in rural area 3. implement black soil protection scheme
33	Glasgow Joint Declaration between China and the United States on Strengthening Climate Action in the 2020s 中美关于在21世纪20年代强化气候行动的格拉斯哥联合宣言	The State Council	Commitment	2021	Methane reduction	2021-2029	**National**			In addition to its recently announced National Determined Contributions (NDCs), China plans to develop a comprehensive and robust National Methane Action Plan with the aim of achieving significant reductions in methane emissions in the 2020s."
34	The National Water-Saving and Drought-Resistant Rice Industry Chain Innovation Alliance was established in Tianjin 全国节水抗旱稻全产业链创新联盟在津成立	Ministry of Agriculture and Rural Affairs	News	2023	**Rice cultivation**		National		reduce emissions from rice cultivation by 20 million tons CO2eq by replacing traditional paddy rice planting methods with newly developed rice breeds that are water-saving and drought resistant, allowing for a 30% reduction in fertilizer reduction and a 90% reduction in methane emissions	
35	National Understory Economic Development Guide (2021-2030) 全国林下经济发展指南（2021-2030年）	National Forestry and Grassland Administration	Guidence	2021	Agroforestry	2021-2030	National (villages)	2025	The total area of forest land under economic management and utilization reaches 650 million acres.	
								2030	The total area of forest land under economic management and utilization reaches 700 million acres.	
36	Notice on Strengthening the Construction and Management of Farmland Protection Forests 关于加强农田防护林建设管理工作的通知	National Forestry and Grassland Administration	Policy	2022	**Agroforestry**		Ntional			Support all localities to coordinate the construction of farmland shelterbelts in conjunction with projects such as forestry and grassland ecological protection and restoration, comprehensive land consolidation, and high-standard farmland construction, and actively build a farmland shelterbelt system that meets the needs of modern agricultural development.
37	List of Top 10 Leading Technologies of the Ministry of Agriculture and Rural Affairs in 2020 2020年农业农村部10大引领性技术名单	Ministry of Agriculture and Rural Affairs	Technical list	2020	Biochar	2020	National			the technique of using biochar as organic fertilizer has been recognized
38	The Third Round of Grassland Ecological Protection Subsidy and Incentive Policies Interpretation 第三轮草原生态保护补助奖励政策解读	Ministry of Finance Ministry of Agriculture and Rural Affairs the National Forestry and Grassland Administration.	Policies Interpretation	2021	Pasture management	2021-2025	Regional	2021-2025	Clearly, the central finance will continue to calculate according to the standard of 7.5 yuan per mu for grazing subsidies and 2.5 yuan per mu for grass-livestock balance rewards in five provinces: Hebei, Shanxi, Liaoning, Jilin, Heilongjiang, and the Beidahuang Farming Group	

39	National Wetland Conservation Plan (2022-2030) 全国湿地保护规划（2022—2030年）	National Forest and Grass Bureau	Planning policy	2022	Wetland management	**2022-2030**	National	2025	Wetland protection rate reaches 55%	establishing 713 wetland reserves—with more than 90 % of natural wetlands effectively protected by 2030; restore 1.4 × 109 ha of natural wetlands; and building 53 national pilot zones for wetland protection and prudent use.
40	National Soil and Water Conservation Plan (2015-2030) 全国水土保持规划（2015-2030年）	Department of Soil and Water Conservation, Ministry of Water Resources	Planning Policy	2015	**Soil and Water Conservation**		National	2020	The country's new water and soil erosion control area is 320,000 square kilometers, of which 290,000 square kilometers are newly added for water erosion control, and the average annual soil loss is reduced by 800 million tons.	
								2030	By 2030, a comprehensive prevention and control system for water and soil erosion that is compatible with my country's economic and social development will be established. An additional 940,000 square kilometers of water and soil erosion control area will be added across the country, including 860,000 square kilometers of new water erosion control area, and an average annual reduction of soil loss of 1.5 billion. Ton.	
41	Opinions on Strengthening Soil and Water Conservation Work in the New Era 关于加强新时代水土保持工作的意见	General Office of the CPC Central Committee General Office of the State Council	Opinion	2023	**Soil and Water Conservation**		National	2025	The national soil and water conservation rate reaches 73%	
								2035	The national soil and water conservation rate reaches 75%	
42	Notice on the issuance of four methodologies including the "Methodology for Voluntary Greenhouse Gas Emission Reduction Projects - Afforestation Carbon Sink 关于印发《温室气体自愿减排项目方法学 造林碳汇》等4项方法学的通知	Ministry of Ecology and Environment	Technical guidance	2023	Relevent LMTs: 1. Afforestation 2. Mangrove reforestraion and cultivation	2023-	National	2023	To introduce guidelines for afforestation, mangrove reforestation, and cultivation carbon sequestration projects in terms of regulating the design, implementation, approval, emission reduction accounting, and verification.	

Annex II: Interview Guide

Interview Questions

Respondent background

1. What is your role?

2. How are you **currently working with LMT**s?

3. From the list provided in the glossary (Annex A), which are the LMT(s) **you are most familiar with?** We will be focusing our discussion on those LMTs you are most familiar with, but trying also to link to trends in China and the region that might affect synergies with other LMTs.

China's LMT profile

4. How would you describe the **current level of implementation and trends in China** regarding the LMTs you are familiar with?

5. Are any particular LMTs being **prioritized in policy and/or implementation**? Do you think this prioritization **might change in the future**?

6. How do you see the **potential role** of land-based climate mitigation practices in **China's commitments to peak emissions by 2030 and achieve net zero by 2060?**

7. What LMTs do you believe possess the **greatest technical potential for carbon sequestration** in the long term to help China meet the **2060/net-zero commitments**?

8. Based on your knowledge and expertise, please review China's policies on LMTs identified in the table (Annex B):
   - Is any policy/target **missing**?
   - How **feasible** are the set targets?
   - How **ambitious and effective** are they considering China's climate goals?
   - Any view on future targets? (e.g. the increment of forest rate observed getting slow, do you think it means China will slow the afforestation or China will set higher targets in the future policies)
   - Are there any conflicts between policies/targets of different documents (e.g. national forestry plan vs. NDC), sectors (e.g. forestry vs. agriculture), or scale (e.g. national vs. provincial)?
   - If there is any conflict as described above, what is the **relative importance of different policies on the same topic?** (which policy/target is prioritized)

9. Do you see **any barriers to the development of LMTs?** How could they be **overcome**?

10. Do you see any challenges or potential **competition between LMTs** when it comes to the domains below? Are some of these challenges already happening? What could be done to manage these tensions?

- availability of land and biomass

- production of food and energy, water resources

- prioritization of climate (carbon sequestration) vs. economic development or other development goals (SDGs)

11. Assuming the launch of the Chinese Certified Emission Reduction (CCER), how do you think it will **positively or negatively impact** various LMTs (such as forestry, agriculture, grassland, and wetland) in terms of their ability to sequester carbon and pursue more ambitious LMT development goals?

Regional engagement

12. Are you aware of any **regional interaction regarding** LMTs? Does **China engage with countries in the region** in ways such as tech transfer, knowledge transfer, capacity building, and capital investment to foster LMT development?

13. What are the main trends in **scaling up LMTs from China national level to Asia regional level** and are there any **opportunities to impact those**?

14. What are the **barriers to scaling up this LMT portfolio** regionally? What is missing?

General closing questions

15. Are there any **resources such as literature, data, models,** etc. that you recommend us look into in terms of the potential and implementation of different LMTs for carbon sequestration in China?

16. Are there any **technical or policy experts on one or multiple LMTs** in China that you recommend us to contact for insights?

17. Are there any additional insights you would like to share with us?

LANDMARC Glossary

- Land-Based Mitigation Technologies and practices (LMTs):

    - Agriculture

        - Agroforestry: Trees are deliberately combined with crops and/or animals on the same unit of land

        - Dry seeded rice – no till: Rice seeds are sown directly in the fields, by directly drilling the soil, instead of transplanting of seedlings.

        - Reduced tillage: A decrease in disturbance to soil during crop cultivation, by reducing inversion tillage.

        - Integrated soil fertility management: Farming method that maximizes the agronomic efficiency of nutrients by using combination of chemical fertilizer, organic residue inputs and improved germplasm.

        - Organic agriculture: An agricultural practice in which organic materials such as animal manures, compost, leguminous plants are applied and avoiding mineral fertilizer application.

        - Biochar: Organic material made by burning biomass in a pyrolysis process, a high temperature (above 300 ºC) and without oxygen, which can be used to improve soil functions and to reduce GHG emission reduction.

    - Forestry

        - Afforestation/reforestation: Afforestation: Establishing forest by planting new trees where there was previously no tree cover. Reforestation: Replanting trees in an area where there was previously forest.

        - Forest management: Process of planning and implementing practices for the use of forests to meet specific environmental, economic, social, and cultural objectives.

        - Forest fire management: Mixture of indigenous fire management and prescribed burning method to suppress and prevent large and uncontrollable forest fires.

    - Bioenergy with carbon capture and storage (BECCS): Energy is generated from biomass and the emitted carbon dioxide is subsequently captured and stored in geological formations.

    - Anaerobic fermentation of manures (biogas/compost): Process of using animal manure, and agricultural or food waste to produce methane as an energy source, and bio-gas slurry as compost.

    - Peatland management: Protection, partial or full restoring (returning degrading peatland areas back to its original state) of peatlands.

    - Pasture management: Management of pasture for greater availability of grazing pastures for animals, maintaining the soil quality and conserving biodiversity.

- Region: The regions considered in LANDMARC are: North America, South America, Africa, Northern Europe, Southern Europe, and Asia.

- Scaling up: to bring a technology or practice from experimental or small-scale implementation at the local level to wide and large-scale deployment at national and regional level.

China LMT Policy Table

LMT	Indicator	Geographical scope	Year	Target	Policy Document
Afforestation	Forest coverage rate	National	2050	More than 26%	National forest management plan (2016-2050)
			2035	26%	National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems (2021-2035)
			2030	25%	China's Action Plan for Reaching Peak Carbon Emissions by 2030 (2021-2030)
					China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy (2021-2030)
			2025	24.1%	China's 14th 5-year plan (2021-2025)
					Outline of the "14th Five-Year" Forestry and Grassland Protection and Development Plan. (2021-2025)
			2020	23%	National Plan for Sustainable Agricultural Development (2015-2030)
			2020	23.04%	13th Five-Year Plan on Greenhouse Gas Emission Control Work Program (2016-2020)
	Forest stock volume	National	2050	23 billion m3	National forest management plan (2016-2050)
			2035	21 billion m3	National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems (2021-2035)
			2030	19 billion cubic meters	China's Action Plan for Reaching Peak Carbon Emissions by 2030 (2021-2030)
			2030	Increase 6 billion m3 compared to 2005 levels	China's implementation of NDC and progress report (2022)
					China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy (2021-2030)
			2025	Reach 19 billion cubic meters	Outline of the "14th Five-Year" Forestry and Grassland Protection and Development Plan.(2021-2025)
			2020	16.5 billion m3	13th Five-Year Plan on Greenhouse Gas Emission Control Work Program
	Natural forest area	National	2035	200 million hectares	National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems (2021-2035)
	Plant, protect and restore	National	2025	1.5 billion trees will be planted in villages	14th 5-year plan on village greening program
			2030	70 billion trees	China's implementation of NDC and progress report (2022)
	Carbon storage of forest	National	2050	3 billion tons	National forest management plan (2016-2050)
	Damage rate of forest and grassland	National	2025	Controlled within 0.9‰ and 2‰ respectively	Ecosystem protection and repairment plan (2021-2035)
			2035	Controlled within 0.8‰ and 2‰ respectively	Ecosystem protection and repairment plan (2021-2035)
Wetland management	Wetland protection rate	National	2035	60%	National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems (2021-2035)
			2025	55%	China's 14th 5-year plan (2021-2025)
					Outline of the "14th Five-Year" Forestry and Grassland Protection and Development Plan. (2021-2025)
			2025	55%	National Wetland Conservation Plan (2022-2030)
Grassland management	Grassland comprehensive vegetation coverage	National	2035	Reaches 60%	National Master Plan for Major Projects for the Protection and Restoration of Important Ecosystems (2021-2035)
					Forestry and Grassland Protection and Development Plan.(2021-2025)
			2020	56%	National Plan for Sustainable Agricultural Development (2015-2030)

Conservative tillage	Cultivated land quality	National	2025	4.58	14th Five-Year Plan on National Green Agricultural Development
	Comprehensive utilization rate of straw	National	2025	86%	14th Five-Year Plan on National Green Agricultural Development
	The area implementing conservative tillage	Northeast	2025	140 million mu	14th Five-Year Plan on National Green Agricultural Development
Organic agriculture	comprehensive utilization rate of poultry manure	National	2025	85%	14th Five-Year Plan on National Green Agricultural Development
	the number of chemical fertilizers reduced in fruit and vegetable tea production areas	National	2020	more than 20%	Action Plan for Substituting Chemical Fertilizers with Organic Fertilizers for Fruit, Vegetable and Tea
	Organic matter content of orchard soil in advantageous production areas	National	2020	reach 1.2% or increase by more than 0.3 percentage points	Action Plan for Substituting Chemical Fertilizers with Organic Fertilizers for Fruit, Vegetable and Tea
Crop rotation	The area of crop rotation	Northeast	2021	5 million mu	Explore the implementation of the pilot scheme of the crop rotation and fallow system
Black soil protection	Protected area	Northeast	2025	100 million mu	14th Five-Year Plan on National Green Agricultural Development
	Protected area High Standard Farmland	Northeast Northeast	2030	250 million mu	Northeast Black Land Protection Planning Outline (2017-2030)
	Protected area	Northeast	2025	50 million acres	
	Quality of cultivated land in the black soil Average content of soil organic matter	Northeast Region Northeast Region	2030	Increase by more than 1 grade (category) on average	Northeast Black Land Protection Planning Outline (2017-2030)
			2030	Reach more than 32g/kg, an increase of more than 2g/kg	Northeast Black Land Protection Planning Outline (2017-2030)
		Northeast Region	2025	increase by more than 10%.	National Black Soil Protection Project Implementation Plan (2021-2025)
	The area of returning organic fertilizer	Northeast		100 million mu of farmland	National Black Soil Protection Project Implementation Plan (2021-2025)
	multiple modes of arable land conservation	Northeast	2025	500 million mu	National Black Soil Protection Project Implementation Plan (2021-2025)
Integrated soil fertility management Biochar	the amount of chemical fertilizers reduced in fruit and vegetable tea production areas	National	2020	more than 20%	Action Plan for Substituting Chemical Fertilizers with Organic Fertilizers for Fruit, Vegetable and Tea
Biochar					
BECCS					

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