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Scaling Agroforestry: Stakeholder Networks and Innovation Pathways Across Institutional Contexts--The cases of China and the Netherlands

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Abstract

Agroforestry systems deliver multiple environmental and socio-economic benefits. While extensive research has validated these outcomes and identified best practices, far less attention has been paid to the fast-evolving stakeholder system and innovations that enable agroforestry to be adopted and scaled out. This paper addresses this gap by mapping how stakeholders and innovations create scaling environments for agroforestry. Using comparative case studies from the Netherlands and China, we map key stakeholders and innovation pathways in these two distinct contexts. In China, the agroforestry stakeholder system is largely comprised of small enterprises embedded in market-led value chains, with innovations and scaling being supported by business-oriented policy incentives, state coordination, and large-scale public programmes. The Netherlands stakeholder system relies more on farmer associations, knowledge networks, and the use of Common Agricultural Policy instruments to coordinate innovation and reward agroforestry as ecosystem services. In both cases, emerging innovations can strengthen the design of incentives, improve measurement and verification of areas under agroforestry and the biodiversity outcomes, and attract private investment for scaling agroforestry systems. Innovations include spatial planning tools, remote sensing and drone-based monitoring, Artificial Intelligence, and carbon credit mechanisms. We suggest that greater international collaboration focused on stakeholder coordination and enabling mechanisms is essential to unlock agroforestry's full potential across diverse national contexts. The contrasting experiences of China and the Netherlands also suggest that pathways for scaling agroforestry are strongly influenced by institutional contexts, offering lessons that other countries may adapt according to their own governance structures, policy environments, and market conditions.

Keywords: agroforestry; stakeholder systems; innovation; policy and governance; scaling and adoption; comparative case studies

JEL codes: Q15, Q18, Q56, O38

1. Introduction

Agroforestry is a land use practice that integrates trees with crops and/or livestock. The environmental and socio-economic benefits of agroforestry systems are well documented in scientific literature (Jose 2009; Thiesmeier and Zander, 2023; Bhandari et al., 2025). However, demonstrating these benefits does not necessarily lead to the widespread adoption and large-scale development of agroforestry systems. The successful scaling of agroforestry depends not only on the performance of the agroforestry system itself but also on how the configuration of stakeholders and innovations influence its adoption,

implementation and long-term sustainability of agroforestry systems. Performance itself depends on the maintenance, and if needed, the restoration of the agroforestry system,

While extensive research has examined the ecological, economic and social outcomes of agroforestry systems, less attention has been paid to the stakeholder systems and innovations that shape agroforestry adoption and scaling (Pantera et al. 2021; Paparella et al. 2025). In practice, scaling agroforestry depends on coordinated actions among governments, research institutions, extension services, farmers, private enterprises, financial organizations, and civil society, each playing complementary roles in knowledge generation, policy support, financing, market development, and implementation. Likewise, successful scaling often requires not only technological innovations, such as improved planting materials of diverse, locally adapted species and provenances, and digital decision-support tools, but also institutional and policy innovations, including incentive mechanisms, certification schemes, and collaborative governance arrangements. Although these elements have been studied individually, there is limited understanding of how they function together as an integrated system to support large-scale agroforestry development.

Another dimension of importance is where, and with which tree species, agroforestry is scaled. Many socio-economically valuable native tree species, including those that form established agroforestry systems, are severely threatened across large parts of their native ranges (Gaisberger et al. 2017, 2022). Most areas important for their conservation are situated outside protected areas, making farmland and community-managed land critical for their persistence (Gaisberger et al. 2022). Targeted species choice that carefully considers the origin and genetic diversity of planting material can effectively support agroforestry scaling.

Stakeholder analysis provides a systematic approach for identifying individuals, organizations and institutions that have interest in agroforestry, assessing and comparing their roles, interests, and influence, and the relationships between them, including collaboration and potential conflicts (Reed et al., 2009; Zinngrebe et al., 2020). Following the stakeholder analysis framework proposed by Reed et al. (2009), this study identifies key stakeholders, characterizes their roles and influence, and examines their interactions within the agroforestry innovation system.

While existing studies have examined agroforestry stakeholders, adoption barriers and innovation needs, they often focus on specific projects, local contexts, community level analyses or particular agronomic and technical dimensions (Barlagne et al. 2023; Ullah et al. 2023; Montero-de-Oliveira et al. 2025). For example, Barlagne et al. (2023) used a participatory stakeholder engagement platform to explore farmer's visions, needs, barriers and pathways for developing multifunctional agroforestry in Guadeloupe, while Tranchina et al. (2024), evaluated agroforestry constraints and digitalization needs through a European multi-actor appraisal.

However, how these stakeholders and innovations interact to enable agroforestry scaling nationally remains insufficiently understood (van der Meulen and Stobbelaar, 2024). Furthermore, stakeholder configurations and innovations vary considerably across countries. For instance, agroforestry expansion may be driven by policy incentives and market mechanisms in some regions, whereas farmer organizations, advisory networks, or local initiatives may play a stronger role in others. Consequently, there is limited comparative understanding of both shared and context specific features of these stakeholder configurations and innovations across countries.

To address this gap, this study asks: (i) Who are the key stakeholders in agroforestry? (ii) What roles do they play in adoption and scaling agroforestry? (iii) What innovations support agroforestry adoption and scaling? These questions are timely given that the surrounding policies, markets and technological environments are changing towards more favorable conditions. New policy instruments, digital and AI-enabled tools, innovative market-led mechanisms, and emerging organizational forms (including producer networks, public–private partnerships, and ecosystem service markets) are also emerging rapidly (Tranchina et al. 2024).

This paper fills a knowledge gap in agroforestry by mapping and comparing the agroforestry stakeholder systems and associated innovations that support agroforestry scaling in two countries that represent contrasting agricultural, institutional, and governance contexts: the Netherlands and China. Using stakeholder mapping and comparative analysis, we examine the roles, interactions, and innovation pathways of key actors involved in agroforestry development. Although agroforestry in both countries lies at the intersection of the agricultural and forestry sectors and aims to enhance sustainability and livelihoods, the structure of stakeholder networks and innovation pathways differs substantially. The comparison identifies both shared enabling factors and context-specific pathways for agroforestry development. It demonstrates how differences in stakeholder coordination and innovation systems shape the scaling of agroforestry and provides insights into strengthening its environmental and socio-economic contributions.

2. Method

This study adopts a broad functional definition of agroforestry as rural, peri-urban and urban land-use and production systems that deliberately integrate woody perennials with crops, livestock or other economically productive understory activities. Under this definition, Dutch farmland-based systems and China's under-forest economy represent institutionally different forms of agroforestry; the comparison therefore focuses on their stakeholder and innovation systems rather than assuming that their biophysical production systems are directly equivalent.

A comparative study design was adopted, drawing on a qualitative typology of agroforestry innovations to examine how governance traditions, market structures and policy priorities shape stakeholder contributions to agroforestry development. Relevant scientific literature, policy documents and grey

literature were identified using predefined search terms and inclusion criteria covering agroforestry stakeholders, policies, innovations and scaling mechanisms in China and the Netherlands.Relevant stakeholders were identified based on their involvement in agroforestry research, policy, implementation, financing, extension, value chains, and farmer support.

Innovations in agroforestry were classified according to their role in supporting agroforestry adoption and scaling, including institutional & policy, technical and digital, market and business model, organizational and network innovations. These innovations surrounding agroforestry are categorized in Table A1 in the Supplementary Material. Evidence was then coded according to the four innovation domains, and stakeholder contributions were classified as 'involved,' 'strong' or 'leading' based on their documented roles in financing, implementation, coordination and decision-making.

3. Results

3.1 Agroforestry stakeholders' systems in the Netherlands and related innovations

The Netherlands has a long history of practicing agroforestry, dating back to traditional mixed farming systems where trees were integrated with crops and livestock for shade, fodder, and timber (Oosterbaan and Kuiters 2008). The Netherlands has seen renewed national and regional interest in agroforestry as a nature-positive climate-resilient practice. National policy and regional planning increasingly recognize agroforestry as a tool for biodiversity, climate mitigation and resilient farming (van der Meulen and Stobbelaar 2024).

The agroforestry landscape in the Netherlands is shaped by a network of interconnected stakeholders spanning research, policy, practice, and finance. Figure 1 presents the core and other stakeholders in agroforestry in the Netherlands, illustrating collaboration among organizations, government bodies, research institutions, and the private sector. The Agroforestry Netherlands Foundation (Stichting Agroforestry Nederland) is part of European Agroforestry, a network of researchers, companies, and organizations involved in the development of agroforestry in the Netherlands. Provincial Agroforestry Networks and farmer associations connect local practitioners to these knowledge hubs, supporting farmers in starting or expanding agroforestry through training, workshops, excursions, and knowledge exchange.

The Food Forest Foundation (Stichting Voedselbosbouw) acts as both a practical implementer and knowledge sharer within the agroforestry network. They focus on the development and realization of profitable food forests and demonstrate best practices that farmers and local networks can learn from. Food forests are a form of agroforestry that imitates natural ecosystems by combining several species of plants in many layers of vegetation including tall canopy trees, fruit trees, shrubs and other low level plants underneath (de Groot and Veen 2017). Food forests are increasingly being established and

registered in the Netherlands, with 231 registered food forests, covering 367 hectares in 2025, up from 54 food forests in 2017 (Centraal Bureau voor de Statistiek, 2026).

Key research institutions provide evidence-based knowledge, pilot studies, and technical support. The advisory organizations and companies translate research into practical guidance, supply materials, develop market links, and support farmers, and government initiatives in implementing agroforestry and food forest projects. Financial institutions enable the adoption of agroforestry by providing green financing solutions, while the National Carbon Market Foundation (SNK) supports carbon-related initiatives, linking environmental outcomes to financial incentives.

The government, represented by the Ministry of Agriculture, Fisheries, Food Security and Nature, Netherlands Enterprise Agency (RVO), and Dutch Emissions Authority, provides policy frameworks, funding, and regulatory support. Policy making and regulation in the agroforestry sector are centralized at the national government level. At the local level, municipalities also play an important role by managing public land, implementing greening and climate adaptation programmes, and supporting initiatives such as food forests and urban tree planting. EU policies, particularly the Common Agricultural Policy (CAP), have a significant impact on agroforestry operations.

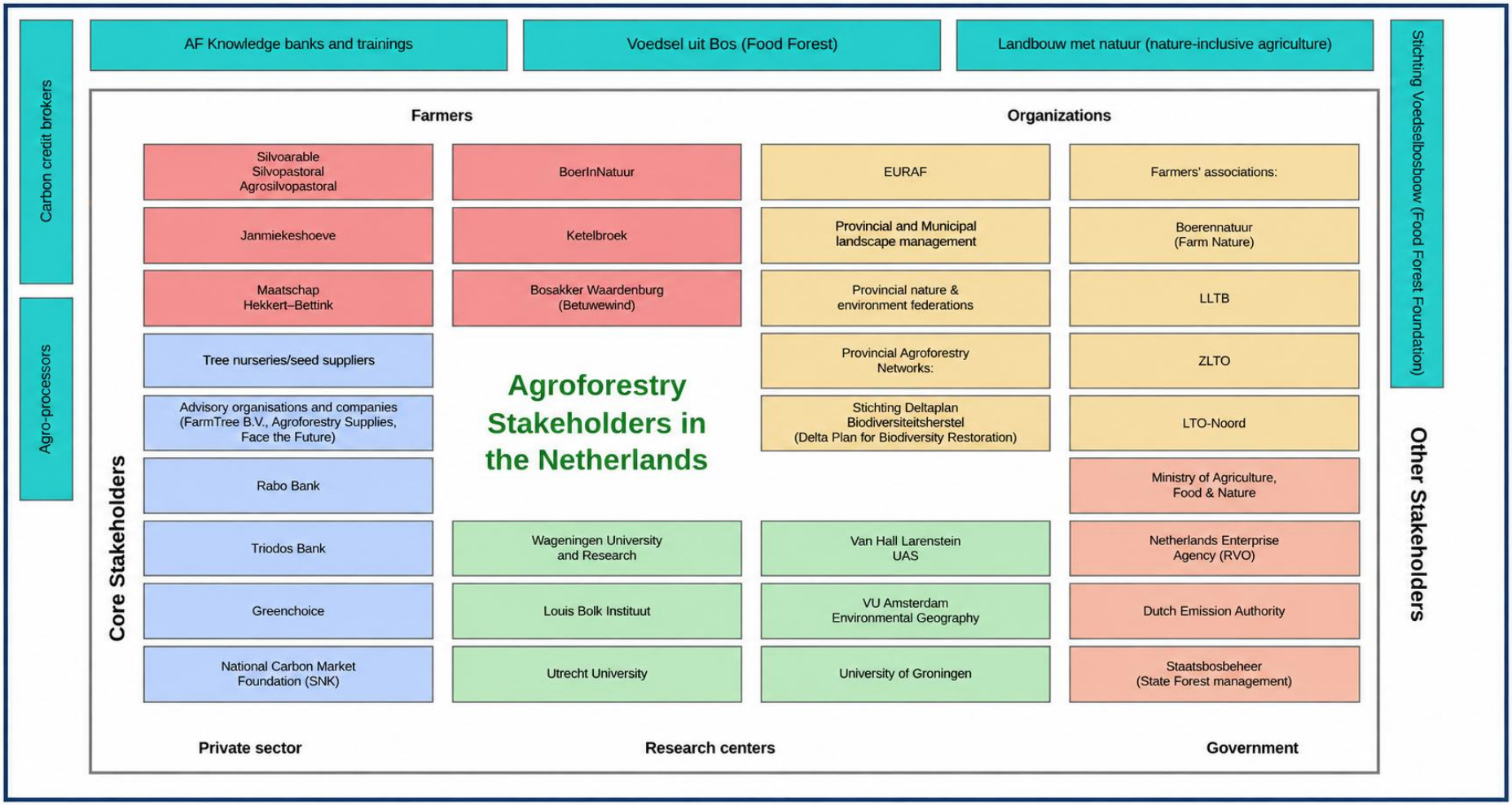

Fig. 1 Main stakeholders in the Netherlands agroforestry landscape

Figure 1 also includes other stakeholders, who have an influence on the agroforestry landscape, but who do not represent a direct driver of operations in the system. These include knowledge banks and training programs, such as 'Voedsel uit Bos (Food Forest)', processors and retailers of produce from agroforestry systems, and general carbon credit brokers.The Dutch living lab brings together farmers, policy makers, advisors and other stakeholders who are involved in testing, adopting and promoting agroforestry innovations under the DigitAF project (https://digitaf.eu/netherlands/; Rastorgueva et al., 2026; Tranchina et al., 2024). Some of the tools tested in the living lab include AgroforesTreeAdvice, BETULA and RegenWorks, which support farmers with species selection and system design; Rekenmodel Agroforestry, INTACT, and FarmTree Tool, for agroforestry economics and tree performance session, and CarboCatch, and CARAT, for carbon and climate. None of these tools deal with the origin or quality of planting resources, or with the conservation status of the species recommended. This is a knowledge gap.

Policy objectives are important in deciding on the course of action and ultimately the effectiveness of different practices. The policy goals of agroforestry in Netherlands include climate change mitigation, landscape recovery, biodiversity enhancement and improvement of soil, water and air quality (Standing Committee on Agricultural Research 2024). Agroforestry has been integrated into policy conversations and CAP Strategic Plans, meaning farmers can potentially access financial support through both Pillar 1 (eco-schemes) and Pillar 2 (agri-environmental measures) for transitioning to agroforestry. The OECD and EU reviews note the Netherlands is actively exploring how to scale agroforestry via CAP instruments and national policy support (OECD 2023; Standing Committee on Agricultural Research 2024).

The Netherlands also supports agroforestry through multiple innovative policy instruments, including its National Climate Agreement and Forest Strategy, transition loans for nature-inclusive farming, Green Deal Voedselbossen (signed in 2019), and research funding via public-private partnerships. Additional subsidies cover planting materials, technology, advisory services, collaboration networks, and nature maintenance, coordinated through initiatives like EIP-AGRI and the Agroforestry Network Netherlands. Agroforestry currently covers 1.5% of utilized agricultural area (Tranchina et al. 2024), therefore there is still room for more inclusive policies and better action to help increase coverage. EU-funded agroforestry projects have significantly propelled the practice forward and enhanced adoption among the various stakeholders in the country. Supplementary Table A2 lists various agroforestry projects in the Netherlands funded by the EU Rural Development Programme, the CAP, and the Horizon multiannual Framework Programmes.

3.2 China stakeholders' systems of agroforestry and related innovations

In China, agroforestry development has been shaped by a strong state-led coordination of policy, research, implementation, and cross-sectoral partnerships that involve government bodies at multiple levels, research institutions, local communities, and international collaborators (People's Daily Online 2025). Agroforestry policy development in China has evolved through forestry, land-tenure and ecological-restoration programmes rather than a standalone national agroforestry strategy. Following rural reforms in 1978, the expansion of the Three-North Shelterbelt Forest Program and farmer-managed tree-crop systems, including paulownia intercropping (Wang and Shogren, 1991), highlighted the role of trees in agricultural production and environmental protection. Subsequent forest-tenure reforms sought to strengthen household rights and encourage long-term investment in trees (Xu and Hyde, 2019). From 1998, the Grain for Green Program further integrated tree planting with ecological restoration through financial compensation, including support for economic forests, although implementation involved trade-offs between environmental objectives, agricultural production and household livelihoods (Duan and Wu 2025; Rodríguez et al., 2016). The revised Forest Law, effective from July 2020, subsequently strengthened the legal framework for forest management and commercial forest use.

More recent policy developments have emphasized forest-based food production and rural economic diversification. The 2023 reform of collective forest rights and the 2024 policy measures promoting a diversified food supply under China's *big food* concept provide opportunities to expand economic forestry and understory production, including fruit, medicinal plants, and mushrooms (Zhang, 2024). Nevertheless, agroforestry remains embedded within broader sectoral policies, creating potential challenges for institutional coordination, tenure security, and access to financial and technical support.

China has emerged as a global leader in agroforestry innovation through its promotion of the "under-forest economy," which integrates high-value agricultural products with forest conservation and rural livelihood development. These systems intentionally combine tree cover with the cultivation of tea, edible fungi, and medicinal plants, thereby supporting biodiversity, improving ecosystem services, and strengthening rural value chains. National forestry strategies, including large-scale ecological restoration and forest tenure reforms, have encouraged diversified forest management approaches that simultaneously enhance economic returns and environmental sustainability (Meng et al. 2025). Such integrated forest-based production models are widely recognized as core components of China's rural revitalization strategy, especially in mountainous and ecologically sensitive regions.

Forest-tea systems are among the most well-documented agroforestry innovations, particularly in Yunnan Province, where traditional tea cultivation is interwoven with natural or semi-natural forest ecosystems. Research on ancient tea gardens demonstrates that tea grown under forest canopies benefits from improved soil fertility, enhanced microbial diversity, and reduced reliance on chemical inputs.

Together they improve tea quality and ecosystem resilience (Zhang and Dong 2025). These systems also support conservation of genetic diversity through the maintenance of ancient tea trees and multi-species forest structures. The Jingmai Mountain ancient tea forest, recognized as a Globally Important Agricultural Heritage System, exemplifies how forest-tea landscapes preserve cultural heritage while sustaining premium tea value chains. Studies further indicate that forest-based tea cultivation enhances microclimatic regulation and soil organic matter, contributing to long-term productivity and climate adaptation (Gui et al. 2022; Huang et al. 2025).

Forest-mushroom systems represent another rapidly expanding agroforestry value chain, driven by increasing demand for edible and medicinal fungi. Under-canopy cultivation of species such as shiitake (Lentinula edodes), and other specialty mushrooms, has been promoted as a mechanism for increasing rural income without compromising forest integrity. Local farmers in Zhejiang province derive around half of their income from mushroom cultivation (FAO 2022a; Tian et al. 2023). Empirical research shows that forest mushroom production improves nutrient cycling by utilizing forest residues as substrates, thereby reducing waste and promoting circular bio economies (FAO 2022a). Additionally, these systems can improve forest health by encouraging diversified understory vegetation management and reducing pressure on wild mushroom harvesting. This practice has historically contributed to forest degradation in some regions.

Silvo-medicinal (forest-medicine) systems constitute a third key pillar of the under-forest agroforestry economy. The cultivation of traditional Chinese medicinal plants beneath forest canopies is increasingly practiced in provinces such as Sichuan, Hubei, and Heilongjiang. Studies indicate that medicinal plant agroforestry enhances species conservation by reducing overharvesting of wild populations while providing alternative livelihood opportunities for forest-dependent communities (Rao et al. 2004). Shade-tolerant species such as ginseng, *Gastrodia elata*, and *Eucommia ulmoides* benefit from forest microclimates that improve phytochemical quality and yield stability. Moreover, forest-medicine systems support multifunctional landscapes by enhancing biodiversity, improving soil structure, and increasing carbon sequestration potential. Policy analyses highlight that government-supported under-forest medicinal production programs have successfully aligned conservation objectives with poverty reduction outcomes in rural areas, according to State Forestry and Grassland Administration of China.

Due to the high population in China, local demand has a big influence on agricultural production. With the growing public interest in sustainability and preference for organic foods, agroforestry has been gaining popularity since there are increased market opportunities for forest-based products, such as the under-forest/understory bamboo mushrooms (Chen and Liu 2025). The under-forest/understory economy is very large scale, utilizing over 600 million mu of forest land (98 million acres), employing 34 million people in 950,000 business entities in the value chain and grossing an output value of over 1 trillion yuan annually (People's Daily Online 2025). The 'three-dimensional bank' at the Qipo state-owned forest farm is a good example of the understory business model. This system, which operates

similarly to food forests in the Netherlands, consists of three layers of vegetation, where the tall trees focus on long-term returns, middle level medicinal materials achieve medium-term harvest and understory Juncao (grass and fungus) are for short term returns. Cultivation in the under-forest economy emphasizes efficient use of understory spaces. It must adhere to principles stating zero disturbance to forest land or interference with natural forest growth, including no usage of chemicals (Chen and Liu 2025). Supplementary Table A3 presents the major agroforestry systems in China.

Most of the Chinese systems rely on a handful of widely planted species, several of them exotic (Pinus elliottii, Taxodium spp.). This kind of strategy has certain risks (e.g., pest outbreaks and climate-related risks) and misses the opportunity to use valued native species. Similar to the Netherlands, the stakeholder landscape for agroforestry in China is also broad and multi-layered, involving government institutions, research bodies, private enterprises, and international organizations. However, the role played by the private sector is more emphasized and the development of PPP has been critical. Processors, retailers and exporters of non-timber forest products (NTFP) including forest tea, edible fungi and medicinal plants are also major stakeholders in China's agroforestry scene, due to the high demand for these products. NTFPs are increasingly recognized as key components in forest-based economy, with the potential to alleviate poverty while preventing biodiversity loss (Wang and He 2026). Figure 2 illustrates the stakeholders.

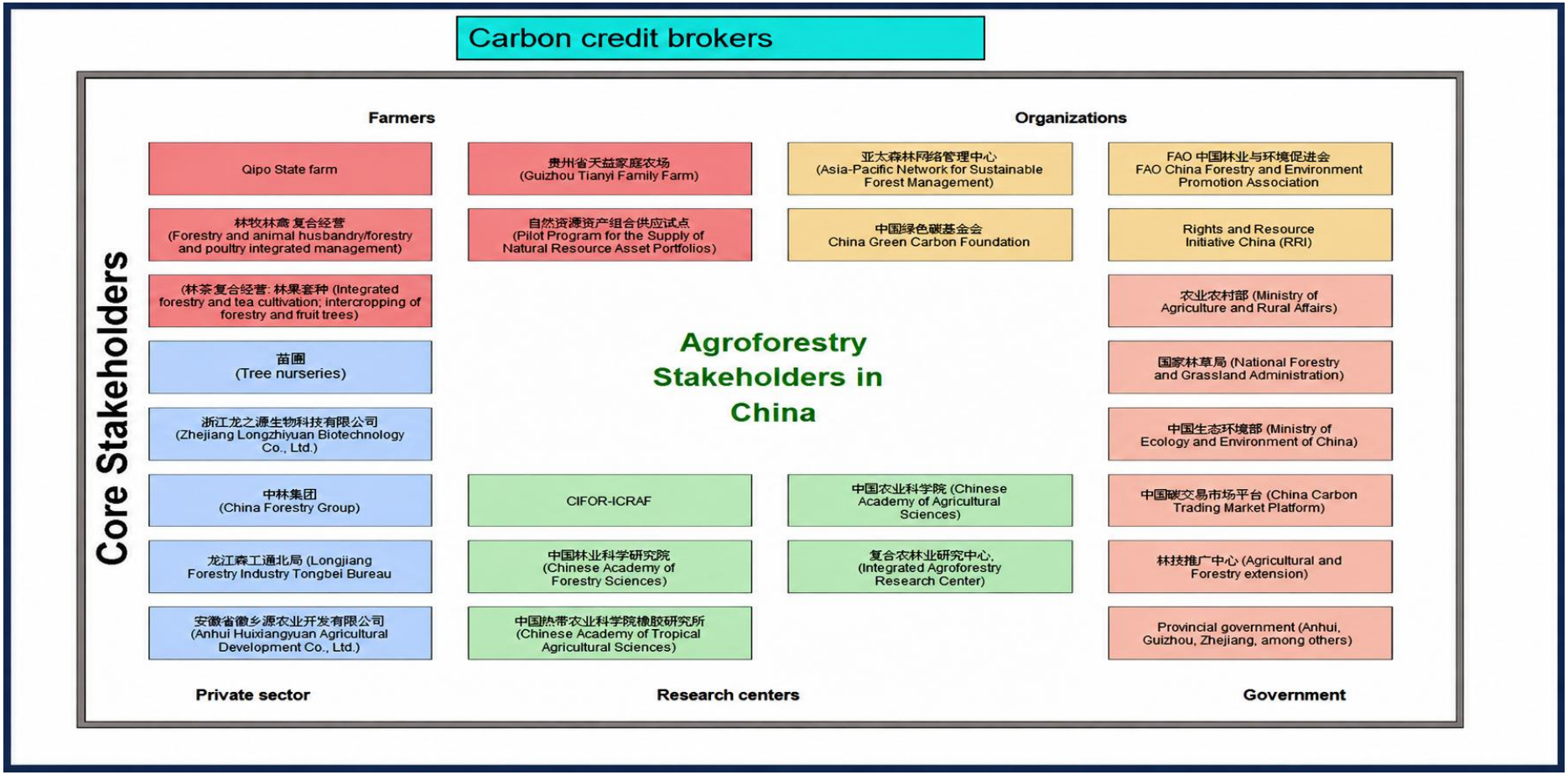

Fig. 2 Main stakeholders in China's agroforestry landscape

In China, companies that sell the products from different agroforestry systems are a key stakeholder group. A key distinction from the Netherlands is that value chain actors for these products from agroforestry systems are key stakeholders, unlike in the Netherlands where they are other stakeholders. On the government side, key actors include the Ministry of Agriculture and Rural Affairs, the National Forestry and Grassland Administration, the Ministry of Ecology and Environment, and the China Carbon Trading Market Platform, supported by agricultural and forestry extension centers and provincial governments such as Anhui Province.

The government plays a key role in the ecological benefits of agroforestry in the country, putting in place the necessary policies, from national foundational practices that have worked for years to more newer strategies, such as the 'bamboo as a substitute for plastic' initiative (Li et al. 2025) The Chinese government is working with bamboo value chain actors, including supporting farmers to venture into the industry, which has increased rural farmer income, and setting up bamboo processing enterprises, which have created employment opportunities.

The research and academic sector play a central role, led by the Chinese Academy of Agricultural Sciences, the Chinese Academy of Forestry Sciences, and the Tropical Crops Research Institute, alongside international partners like the Center for International Forestry Research and World Agroforestry (CIFOR–ICRAF) office in China. These institutions advance technical innovation, policy research, and capacity development in agroforestry. Carbon-related initiatives like CCER (China Carbon Emission Reduction) and green enterprises such as the Organic Farming Association and China National Agroforestry Group contribute to market mechanisms and financing. International and civil society organizations, including the Asia-Pacific Network for Sustainable Forest Management, Asia Pacific Forest Genetic Resources Programme (APFORGEN), China Green Carbon Foundation, FAO China, and Rights and Resources Initiative (RRI), facilitate policy dialogue, technical exchange, and sustainability partnerships

Innovations in China's industries are mostly about new products and processes, where business models are adjusted to fit the current demand trends and meet them in the most profitable methods. The agroforestry sector is no different, where the focus is on improving the understory economy and the business model around it. This includes methods of improving yields from forest-teas, forest-mushrooms and forest-medicine, value addition, and marketing of these products.

China advances its agroforestry through a combination of top-level strategies, industrial and agriculture policies, and legal regulations. These measures cover a broad spectrum**,** from sustainable agricultural and forestry management and the application of new technologies to the introduction of under-canopy (**林下种植**) models. The following are the main elements that underpin China's bioeconomy: National strategies including the 14th Five-Year Plan for Economic and Social Development (FAO 2022) lists the

agroforestry as a strategy for the adjustment of agriculture sector[1], setting clear priorities for coordination of agriculture with forestry, which is part of the vision to increase forest coverage to 26% by 2035, and increase tree based food production. These plans specifically emphasize the model of agroforestry for sustainable agricultural production and the development of high-quality production systems to advance green and efficient agricultural development. The central government has emphasized the development of agroforestry. Notably, the China's 2025 No. 1 Central Document explicitly calls for "developing the full industrial chain of the forest-based economy", as a key pathway to strengthen ecological industries and rural prosperity). Major national ecological restoration programs, such as the Three-North Shelterbelt Program, the Grain for Green program (GFG), and the Yangtze River and Yellow River basin rehabilitation projects, have revitalized tree-based farming across the country. The GFG program has had a major impact: compensation sometimes exceeded the previous agricultural revenues of farming households. This led to a surge in agroforestry technologies including fruit tree intercropping.

The National Forestry and Grassland Administration (NFGA) coordinates large-scale programs that integrate trees into agricultural landscapes, including the Grain for Green Program, the National Forest Villages Initiative, and Ecological Function Zoning. Under the 14th Five-Year Plan (2021–2025), agroforestry is explicitly promoted as part of "ecological civilization" and "nature-based solutions" for climate mitigation. Financial incentives include ecological compensation schemes, subsidies for fruit and timber intercropping, and payments for ecosystem services in key watersheds. Several pilot provinces, such as Sichuan, Yunnan, and Guangxi, also provide tax reductions, carbon credit opportunities (Red net moment 2024), and green financing for agroforestry enterprises. Increasingly, policy emphasizes innovation, linking farmers, research institutes, and private companies to scale up profitable, climate-smart, and biodiversity-friendly agroforestry practices across the country.

4. Comparing the two countries

The agroforestry stakeholder–innovation analyses for the Netherlands and China reveal two distinct but potentially complementary configurations of stakeholder contributions across innovation domains. Each country exhibits a coherent internal logic shaped by its governance traditions, market structures, and policy priorities, resulting in different pathways for enabling agroforestry innovation (Table 1).

Table 1. Comparative table of agroforestry models in the Netherlands and China

[1] More information are listed at (https://www.gov.cn/zhengce/zhengceku/2021-09/07/content_5635867.htm)

Comparative dimension	Netherlands	China
Lead sector and principal authority	Agriculture-oriented governance. Ministry of Agriculture, Fisheries, Food Security and Nature.	Forestry-oriented governance. National Forestry and Grassland Administration
Land classification	Primarily implemented on existing agricultural land. Agroforestry generally does not fundamentally change agricultural land classification.	Primarily associated with forestland Implementation takes place within existing forestry and land-use frameworks.
Dominant systems	Food forest, silvopastoral systems	Agrosilvicultural system, silvopastoral system, agrosilvopastoral system
Main policy instruments	Subsidies (Common Agricultural Policy (CAP))	Natural Forest Protection Program, Grain for Green policy, Forestry policies, National ecological restoration programmes.
Key intermediaries	Provincial Agroforestry Networks, NGOs, private companies, financial institutions, farmer associations	Less prominent independent intermediary networks; coordination mainly through government and extension institutions
Main objective	Climate change mitigation, biodiversity enhancement, soil and water quality improvement	Ecological restoration, forest conservation, farmers' income diversification
Main barriers	Limited farmer awareness and technical knowledge. Economic risks and long investment periods Land-use and regulatory constraints. Need for improved market development and financial incentives.	Balancing forest conservation and economic equality. Institutional and regulatory complexity. Dependence on government coordination.
Digital and MRV tools	DigitAF living lab. AgroforesTreeAdvice, BETULA and RegenWorks. Rekenmodel Agroforestry, INTACT, FarmTree Tool, CarboCatch and CARAT.	Government-led technical and digital innovation. Forestry monitoring and digital management systems.

In the Netherlands, stakeholder contributions are relatively balanced across innovation domains, with particularly strong roles for farmer organizations, associations, and research institutes in organizational and network innovation. This reflects a governance model centered on coordination, collective learning, and knowledge exchange, where innovation is mediated through dense networks and supported by enabling policy instruments. Private companies and farmers also show substantial engagement in technical and market-related innovations, suggesting an incremental, network-driven approach to scaling agroforestry that emphasizes risk-sharing and ecosystem service provision.

China, by contrast, displays a more centralized pattern. Government actors dominate institutional and policy innovation, underscoring the central role of state coordination and top-down policy frameworks in shaping agroforestry development, including the promotion of market and business models. Private companies and farmers also contribute to market and business model innovation, reflecting the importance of value-chain integration and income diversification within China's agroforestry systems. Organizational and network innovation is comparatively weaker and more centralized, indicating less reliance on intermediary associations and bottom-up coordination.

Agroforestry is also managed under different institutions. In China, agroforestry is institutionally framed primarily within the forestry sector rather than agriculture, reflecting broader governance, policy, and political priorities. This orientation is closely linked to the administrative authority of forestry agencies over forestland, as well as national ecological restoration agendas such as the Natural Forest Protection Program and the "Grain for Green" policy. Framing agroforestry as part of the "under-forest economy" (林下经济) enables the state to promote rural income generation and market development while maintaining forestland classification, ecological targets, and forest-cover statistics. It also aligns agroforestry with the broader political discourse of "ecological civilization," in which forests are positioned as strategic ecological infrastructure for climate mitigation, biodiversity conservation, and rural revitalization. Thus, China's agroforestry pathway is shaped less by agricultural modernization narratives and more by state-led ecological governance and forestry-based rural development strategies.

In contrast, agroforestry in the Netherlands is more commonly framed within the agricultural sector because it is primarily embedded in agricultural land-use systems, farm policy frameworks, and agri-environmental objectives. Dutch agroforestry initiatives are generally implemented on existing farmland and are closely linked to multifunctional agriculture, climate-smart farming, and ecosystem service provision. As a result, agroforestry is largely governed through agricultural institutions, farmer organizations, and CAP instruments rather than through forestry administration. This institutional framing reflects the Netherlands' historically intensive agricultural model, where, in recent years, trees are increasingly integrated into farming systems to enhance biodiversity, soil quality, carbon sequestration, and landscape resilience. This is done without fundamentally changing agricultural land classification. Compared with China's forestry-centered approach, the Dutch model positions agroforestry primarily as an innovation in sustainable agriculture, emphasizing farmer-led experimentation, knowledge exchange, and incentive-based environmental governance. Historically speaking, it is not a pure innovation though since in pre-modernization times, farmers integrated trees into their farming systems.

The two cases highlight complementary strengths. The Dutch model offers insights into how networked governance and intermediary institutions can align ecological objectives with innovation processes. The

Chinese model demonstrates how strong state leadership and market orientation can accelerate scaling. Cross-country learning between these approaches could create synergies between coordination, scalability, and sustainability in agroforestry transitions.

The roles of different stakeholders in supporting agroforestry innovations vary between the two countries. Figure 3 presents a stakeholder-innovation crosswalk comparing the Netherlands and China. Each matrix maps the five stakeholder groups against the innovation domains introduced above. Cell shading indicates the strength of each stakeholder group's contribution, ranging from none to involved, strong and leading. The two matrices make visible the contrasting governance logic discussed in this paper.

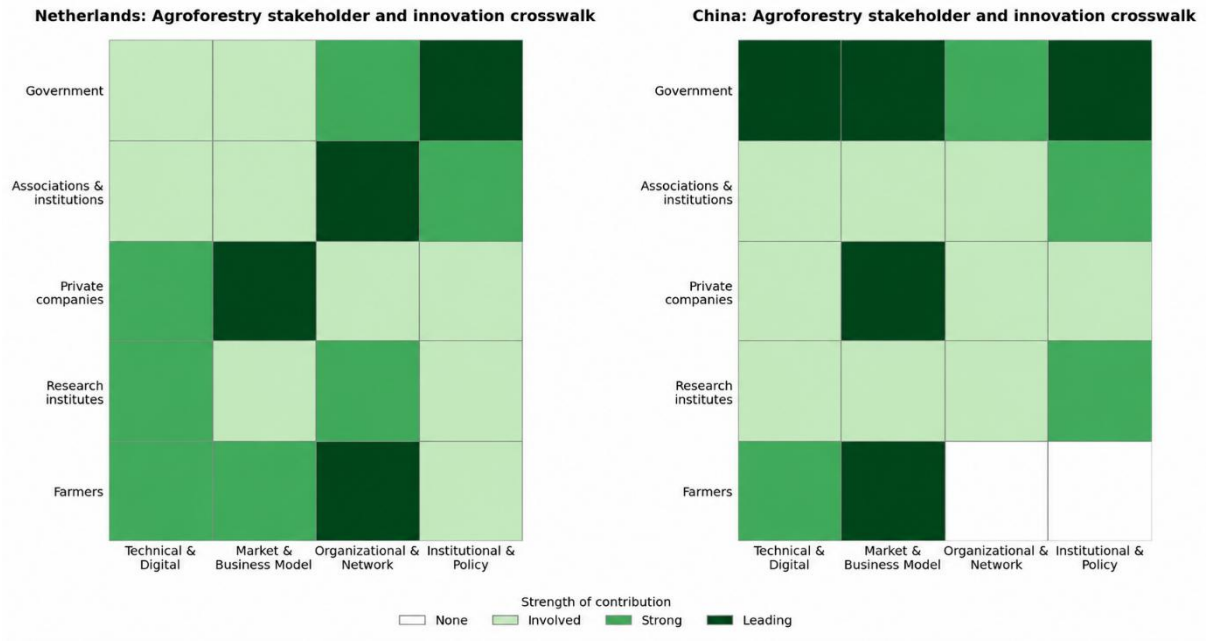

Fig. 3 Comparative stakeholder–innovation matrix showing the roles of key agroforestry stakeholders in supporting different innovation domains in the Netherlands and China.

In the Netherlands, contributions are spread more evenly across stakeholder groups, with associations and institutions, together with farmers, playing leading roles in organizational and network innovation, consistent with a coordination-based, network-driven governance model. In contrast, the Chinese government dominates across most domains, taking a leading role in technical and digital, market and business model development, institutional and policy innovation, reflecting the more centralized, state-led pattern characteristic of China's agroforestry governance.

In the Netherlands and China, agroforestry is practiced enhancing sustainable land use, agrobiodiversity, carbon sequestration and diversify farm income. However, there exist differences in the emphasis in the two countries. In the Netherlands emphasis is placed on the ecosystem benefits of agroforestry, while in China the focus is more on diversifying income sources for farmers through agroforestry. The Netherlands reflects a networked, association-driven model in which farmer

organizations, SMEs, research institutions, and EU-aligned policy instruments play a central role. China, by contrast, illustrates a farm- and enterprise-led model embedded within strong state coordination, large-scale public programmes, and vertically integrated policy support.

This comparison has several limitations. Agroforestry is institutionally framed mainly within agriculture in the Netherlands and forestry in China, which limits direct comparison. The findings should therefore be interpreted as insights from two contrasting cases. Future research could validate the stakeholder classifications through systematic interviews or surveys and examine how different stakeholder configurations affect measurable adoption and scaling outcomes. It could also address the spatial and biophysical dimensions of scaling, i.e., where agroforestry could expand and with which species and planting material. This could demonstrate if and how scaling contributes to the conservation and restoration of tree diversity (Gaisberger et al. 2022).

5. Conclusion

This paper sets out to move beyond biophysical and farm-level analyses of agroforestry by examining the stakeholder systems and innovation dynamics that enable agroforestry adoption and scaling in practice. Through a comparative analysis of the Netherlands and China, the study demonstrates that agroforestry development is shaped not by a single optimal model, but by context-specific configurations of actors, institutions, markets, and policy instruments. While the two cases differ markedly in governance structures and innovation pathways, they reveal shared challenges and opportunities that carry important implications for other national contexts.

Agroforestry adoption and scaling depend on the coordinated actions of a diverse set of stakeholders, each contributing different resources, knowledge, incentives and institutional support. In both countries, key stakeholder groups are the same but the ways in which roles are played differs. Key stakeholder groups include farmers and farming communities, government institutions (in China centered around the forestry sector, in the Netherlands around agriculture), research and academic organizations, extension services, NGOs and development partners (playing a stronger role in the Netherlands than in China), private-sector actors, financial institutions, and community-based organizations (more strongly present in the Netherlands than in China). In both countries, farmers remain central to adoption because they make decisions about land use and management, while other stakeholders shape the enabling environment in which those decisions are made. In China, the government plays a very strong role in the four innovation domains while in the Netherlands this role is more evenly distributed among the five stakeholder groups.

Stakeholders can play complementary roles in adoption and scaling. Farmers test, adapt, and implement agroforestry practices based on their needs and local conditions. Government provides policies, regulations, incentives, extension systems, and institutional coordination.Research organizations generate evidence, technologies and locally appropriate practices.Extension agents and NGOs facilitate

knowledge transfer and capacity building.Private-sector actors strengthen access to inputs, markets, value chains, and investment; and financial institutions and development partners help address the financing and risk constraints that can limit adoption. Scaling therefore requires moving beyond isolated projects towards coordinated systems that connect knowledge, finance, markets, policy, and local implementation.

Among the innovations supporting agroforestry, the most important are those that reduce adoption barriers while increasing the economic, environmental, and practical benefits to farmers. These include improved and locally adapted tree varieties and planting materials from genetically diverse seed sources; spatial targeting tools that show where agroforestry can deliver conservation and restoration benefits; digital tools for extension, information, and monitoring; innovations in nursery production and tree establishment; integrated tree-crop and tree-livestock systems; improved market and value-chain solutions for agroforestry products; and financing and incentive mechanisms that reduce the upfront costs and risks of adoption. Overall, the most critical innovation is not a single technology, but the combination of technical, institutional, financial, digital, and market innovations that make agroforestry viable and scalable for farmers.

The case study analysis of both countries points to the need to consider trade-offs between more government directed and more market directed pathways. In China, with a very strong government role, considerable scaling has taken off but key issues have emerged related to (insecure) land tenure, Grain for Green tradeoffs, and inequality in the distribution of benefits. In the Netherlands, where government interventions have been less directive than in China, uncertainty about land classification and long pay back times on private investments have to date led to a slow pace of scaling. Market mechanisms alone tend to prioritize short-term profitability and easily monetized outputs, while public policy is essential to address long investment horizons, risk exposure, and the provision of public goods such as biodiversity, carbon sequestration, and landscape resilience. In both cases, government plays a critical role in setting strategic direction, reducing uncertainty, and enabling coordination among diverse actors, while markets provide the demand signals, investment capital, and innovation incentives needed for scaling. This dual reliance suggests that policy debates framed as state versus market interventions risk oversimplifying the conditions required for successful agroforestry transitions.

The comparison shows that achieving a balance between market-based economic value and ecological value remains difficult, even in relatively advanced agroforestry systems. While both cases demonstrate pathways to enhance either income diversification or ecosystem service delivery, integrating these objectives in a stable and equitable manner remains challenging. Tensions persist between profitability, risk distribution, and long-term ecological outcomes. Addressing this balance is central to agroforestry's future role as a nature-based solution and requires coordinated stakeholder action, credible measurement and verification systems that also capture biodiversity outcomes, including tree species diversity, and policy frameworks that reward both private and public benefits.

Another insight concerns the dynamic interaction between innovation and stakeholder systems, and the persistent challenge of policy lag. Digital tools, monitoring technologies, artificial intelligence, and carbon accounting mechanisms are advancing rapidly and reshaping how agroforestry systems are designed, evaluated, and financed. However, policy frameworks and regulatory instruments often struggle to keep pace with these innovations. In both the Netherlands and China, mismatches between technological potential and policy recognition can limit adoption, delay investment, or create uncertainty for farmers and enterprises. Aligning policy development more closely with innovation trajectories, including adaptive regulation and experimental policy instruments, is therefore crucial for sustaining momentum.

A key finding is that substantial cross-country learning, which could be relevant for other countries as well, remains under-exploited. The Dutch case illustrates how dense knowledge networks, farmer associations, and policy instruments focused on ecosystem services can foster experimentation, reduce risks, and support nature-inclusive farming. China, in contrast, shows how strong state coordination combined with market-oriented value chains and enterprise engagement can drive rapid scaling and income diversification. These approaches are often discussed separately in literature, yet the comparison highlights their complementarity. Countries seeking to expand agroforestry could benefit from selectively combining elements of both models, such as pairing market-driven value chains with stronger institutional coordination or embedding ecosystem service incentives within commercially viable production systems. More systematic international exchange of institutional designs, technologies, and governance experiences could accelerate learning and avoid the repetition of policy and implementation of failures.

Overall, this study highlights agroforestry as a socio-institutional transition rather than a purely technical intervention. Unlocking its full potential will depend on strengthening stakeholder coordination, fostering cross-country learning, and designing enabling mechanisms that bridge markets, policies, and ecological objectives across diverse national contexts. Meeting climate, biodiversity and restoration goals will require planting many more trees, not only on farms but also in urban and peri-urban areas, where agroforestry and food forests can provide food, shade and cooling close to where most people live. Achieving this at scale will in turn depend on a reliable supply of diverse, locally adapted planting material.

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