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Perspectives of plantation forests in the sustainable forest development of China

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Modern forestry is gradually moving towards man-made forests on a large scale. Plantations with advanced forestry system have been introduced with the goal of sustainable forestry development and to enhance social, ecological, and economic benefits. Forest plantations with native and exotic species have been established in China and worldwide with shorter rotation cycles than natural forests. In this paper, we discuss the role and perspectives of plantation forests in the Chinese sustainable forest development, the evolution of various plantation programs, the ecological effects of plantations, and the measures to improve plantation forestry. The Chinese government has given substantial importance to nurturing plantation forest resources through various large scale afforestation programs. In 2019, the total area covered by plantations in China reached 79.54 million ha, with a stock volume of 3.39 billion m^3 (59.30 m^3 per ha); coniferous forests (26.11 million ha, 32.83%) and broad-leaved forests (26.45 million ha, 33.25%) are the dominant types. Plantations have been primarily distributed in the central and southern parts of the country. Plantations with fast-growing and high-yielding tree species facilitated Chinese afforestation activities and improved the administration of forest production, which effectively boosted the forest industry. Plantation forest resources offer many potential productive, economic, and social advantages, though they are also associated with a loss of biodiversity and climate change makes them likely susceptible to disease and insect attack. Appropriate forest management practices during planning, execution, and maintenance of plantations can contribute to the conservation, promotion, and restoration of biodiversity, with the final aim of attaining a balance between having forest plantations and natural forests.

Keywords: Chinese Fir, Poplar, Eucalyptus, National Forest Inventories of China, Ecological Implications

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Introduction

Cultivating plantations is an effective way to preserve and protect natural forest resources. Artificially reconstructed forests play a critical role in improving the environment, promoting industrial restructuring, and alleviating timber supply pressure (Aronson & Alexander 2013, Wang et al. 2017). The rise of the 20th century brought rapid development in the industrial world; thus, the race of vast accumulation of wealth negatively impacted the world's forests, and forest areas sharply decreased in many countries/regions (Trumbore et al. 2015). Transport infrastructure for mining/energy, road construction, industrial logging, agricultural expansion, and wildfires were significant drivers of forest coverage loss (Scullion et al. 2019). Since 1990, an estimated 420 million ha of global forest coverage has been lost due to deforestation. In most recent times (2015-2020), the annual deforestation rate decreased from 12 million (2010-2015) to 10 million (FAO 2020), mainly by increasing plantation forests. There is a significant concern whether natural forests can cope with the demand for sustainable development of human society (Oliet & Jacobs 2012).

China is well-known for its varied climatic and geomorphological conditions, and for its vast land territory, which provides an inclusive background for vegetation establishment and tree species growth. China's forest land has been cleared over the decades by agricultural expansion. At the founding of Peoples Republic of China in 1949, the forest cover was merely 9% of the total land area. Even further deforestation happened in the 1970s (Yu et al. 2011, Miao et al. 2013). Just three decades before, China was one of the countries with the lowest forest area *per capita* worldwide. Natural forests and plantations were deficient and unevenly distributed with low quality (Lü et al. 2011, Xu et al. 2012).

The unprecedented economic development of China and the fast population growth have led to a dramatic upsurge of wood consumption in many regions, resulting in several well-known ecological disasters such as soil erosion and flooding (Yin et al. 2005). This caused unmeasurable environmental damage with long-term social and economic impacts (Aronson & Alexander 2013). However, emergency measures were taken to overcome this, and today China has the most extensive plantation

Tab. 1 – Main structural and silvicultural differences between natural forests and plantations in China (Avtar et al. 2014)

Natural forests	Plantations
Multi-layered	Single-layered
Complex structure	Simple structure
Multispecies	Usually single species (monoculture)
Flora and fauna richness	Poorer flora and fauna
High biomass density	Less biomass density
Sequester more carbon	Sequester less carbon
Continues plant growth	Initial fast growth
Time-consuming forest inventory	Fast and easy forest inventory
Labor intensive forest management	Cost-efficient forest management
High uncertainties in inventory data	Inventory data has fewer uncertainties
Natural rotation cycle	Generally short rotation
No fixed but continued return	Economic return after a fixed time
Higher ecological benefits	Higher timber yield

area worldwide (Zeng et al. 2015).

With the rapid increase of the economy, the demand for timber increased, affecting the natural forests; therefore, many conservation programs were launched in China to protect natural forests. To ensure a sustainable forest development, various measures have been taken by the Chinese government on an emergency basis. Multiple programs were introduced such as the "China Natural Forest Protection Program" (Ren et al. 2013, Zeng et al. 2015), "China Fast-Growing and High-Yield Plantation Program", "Integrated Intensive Forest Management (IIFM) Project", "Research on China's Plantation Woods" etc. (Zhang et al. 2010, 2016). Afforestation of scarsely forested lands was implemented, and legal harvesting in natural forests was significantly reduced. High yielding and fast-growing timber species were introduced to cope with the ever-increasing timber demand. Relevant sectors and industries have been encouraged and promoted to gain substantial benefit by steadily enhancing the technical and administrative levels. Besides playing its role in the national economy and social development by improving timber and non-timber forest goods, plantations also play a vital part in enhancing the ecological environment in many areas.

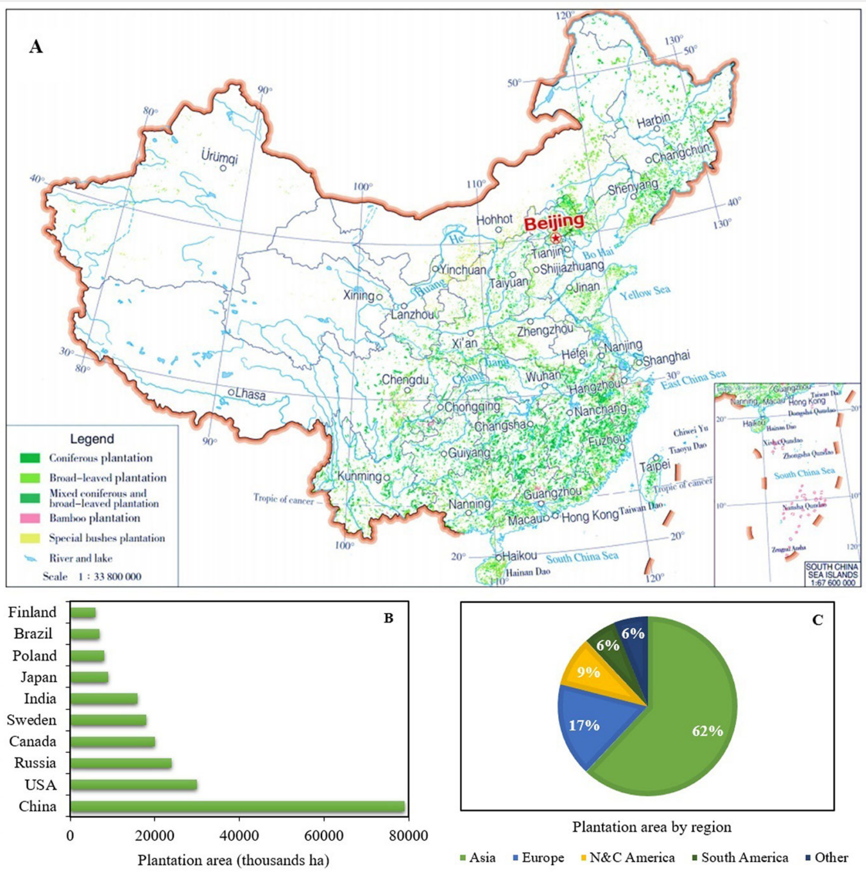

Fig. 1 - (A) Distribution of area under plantations in China (SFA 2019); (B) major countries in terms of tree planting area (in thousands ha); (C) plantation area (%) by region.

Although natural forests provide higher environmental services than plantations (Yamagawa et al. 2010, Xu et al. 2012), the latter also play a vital role by provisioning clean air and water protection. Plantation forests can provide most services such as woody and non-woody products, biodiversity, aesthetics, carbon sequestration, climate control, and soil erosion control (Sasaki & Yoshimoto 2010, Ruiz-Jaen & Potvin 2011, Farooq et al. 2019a, 2019b, 2019c). Plantations grow much faster than the natural forests, having specific value in terms of timber supply, fast forest spread, and ecosystem conservation (Chinnaraj & Malimuthu 2011, Farooq et al. 2018, 2019a, 2019b). Hence, plantations have become a crucial part of China's afforestation efforts to tackle climate change and air pollution (Zeng et al. 2015). Tab. 1 reports the main structural and silvicultural differences between natural forests and plantations in China. The interest in plantations was relatively scarce in the past; however, the concept and related practices are not new (Paquette & Messier 2010, Gerber 2011).

In this paper, the Chinese approach to developing plantation forests and its progress over the years is reviewed, including their current status and perspectives. Moreover, we discuss the ecological implications and measures for their improvement.

Materials and methods

This study was carried out based on the published data (1970-2020) collected from Clarivate Web of Science® (http://apps.webofknowledge.com/) and the China Knowledge Resource Integrated Database (http://www.cnki.net/), using the terms "plantation forest", "sustainable forestry", "forest sector", "ecological implication", and "ecological impacts" as keywords. Moreover, some common grey literature such as reports, evaluations, and government documents were also used to fulfill minor information gaps. According to the relevance of publication title and abstract, we excluded studies that did not precisely meet our objectives. Various publications and documents reporting similar data were excluded to avoid duplication. Overall, data from 99 studies were used, including journal and non-journal resources.

Status of plantations and evolution of reforestation programs

The Chinese government has given substantial importance to nurturing forest plantations, and many large scale afforestation and regreening programs were carried out. Currently, China has the most extensive plantations with the highest afforestation rate worldwide, mostly using fast-growing species (Yang et al. 2010). In the last three decades, China has planted about 6.6 million ha of forest area every year due to the national forest protection programs, with an average increase of 1.1% per year. Since the government first introduced a nationwide tree-planting program in 1981, volunteers have planted over 45 billion trees.

Currently, the area under plantation in China ranks first in the world (SFA 2019). The total area of plantations reached 79.54 million ha in 2019, with a stock volume of 3388 billion m^3 (59.30 m^3 per ha). Coniferous forests (26.11 million ha, 32.83%) and broad-leaved forests (26.45 million ha, 33.25%) are the dominant types (Fig. 1). The government is currently looking to implement forest policy measures to increase the spread, quantity and quality of forests with the aim of increasing forest cover to 23% by 2020, and to 30% by 2050.

Plantation resources have been primarily distributed in the central and southern parts of the country. Provinces including Guangdong, Guangxi, Hunan, Inner Mongolia, Sichuan, Yunnan have a significant cover of plantations (Farooq et al. 2019a), accounting for 43.50% of the total national plantation area (SFA 2019). The area of the young plantations (1-10 years), middle-aged plantations (10-20 years), near-mature plantations (around 25 years), mature plantation (25-35 years), and over mature plantations is 23.26, 16.97, 8.09, 6.59 and 2.23 million ha, respectively; the stock volumes are 585, 1115, 723, 720, and 245 million m^3, respectively (Fig. 2).

According to China's 9th forest inventory report for the period 2014-2018 (Fig. 3), the standing volume stock of plantations accounts for 19.24% of the entire volume stock in the country (Zeng et al. 2015). Due to high domestic demand, plantation area is expected to increase rapidly. Out of the total plantation area, 36.26% has been planted with cash trees crops, 3.1% with bamboo plantations, and the remaining 60.64% with other species. Plantations for timber production cover the most significant area, accounting for 70% of the total plantations and including protective, fuelwood, and special-use plantations (SFA 2014). Several dominant softwood and hardwood species were introduced during reforestation programs in China (Bao & Jiang 1998). Plantations have been established using more than 2500 different tree species, the most used being Chinese fir (*Cunninghamia lanceolata*), Poplar (*Populus* spp.), and *Eucalyptus* spp., which account for 50% of all planted species (SFA 2019 – Fig. 4). A list of the main tree species used in Chinese plantations are reported in Tab. 2. The total plantation area of the ten soft-

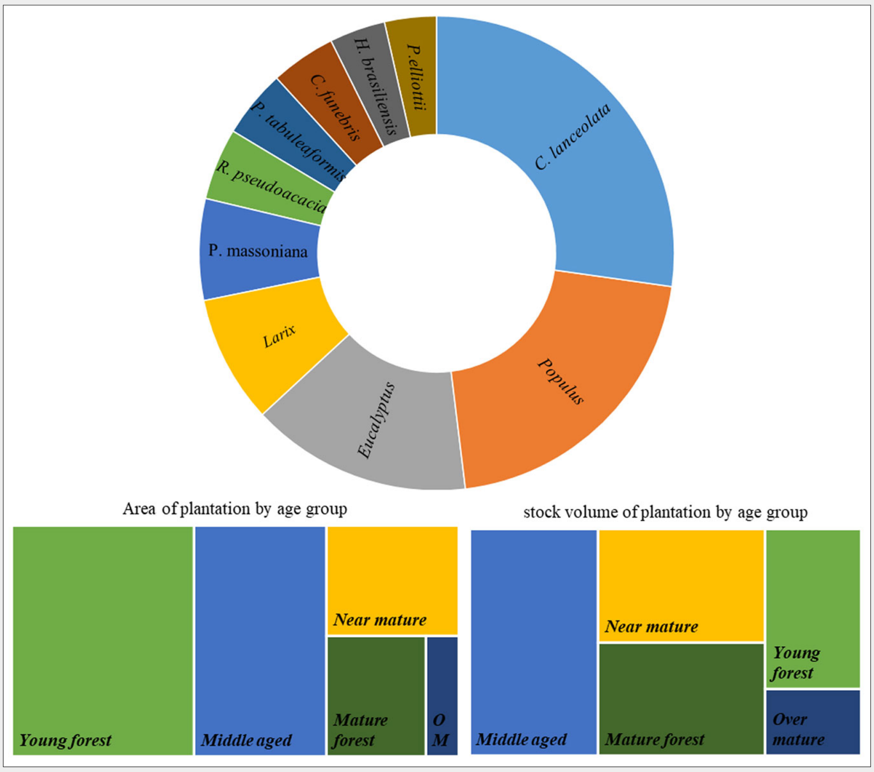

Fig. 2 - (above) Partition of the total plantation area in China by dominant species; (below) partition of the total plantation area (left) and stock volume (right) by different age groups (Zeng et al. 2015).

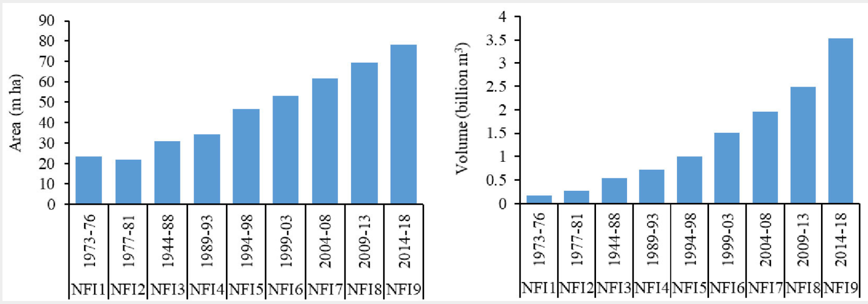

Fig. 3 - The increase in surface area and growing stock volume of plantations forests in China from nine national forest inventories (NFIs). Source: ninth national forest inventory (2019).

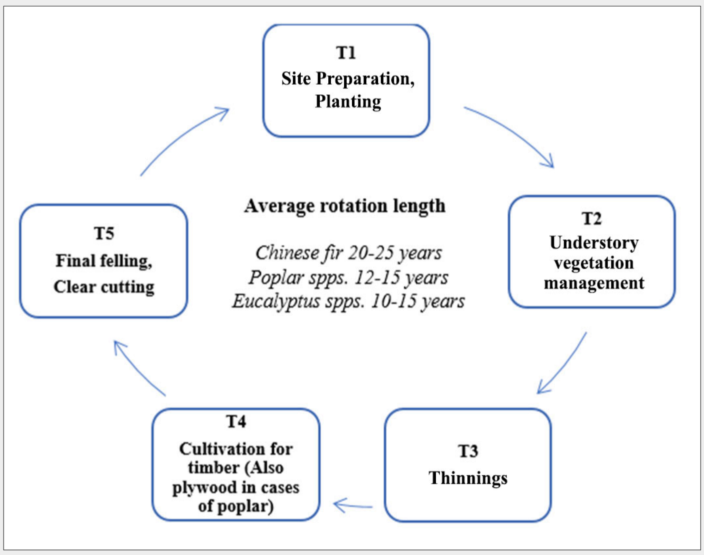

Fig. 4 - The silvicultural cycle of the three dominant species in Chinese plantations (Chinese fir, Poplar, and *Eucalyptus* spp.).

wood species amounts to 63.65% of the national total, and their stock volume accounts for 68.47%. Plantation stands in the uplands of China also protect the lowland river valleys from the severity of droughts and floods by preventing erosion, and making the intensive irrigated agriculture system conceivable (Bao & Jiang 1994, Bao & Lu 1998). For rural households, these stands are the source of 40% of the fuel, making China one of the world's most forest-dependent countries.

In the last two decades, many afforestation projects have been started to establish high yield and fast growing stands (Fig. 5). These programs include: (1) CCPF (covering 25 provinces); (2) NFPP (covering 17 provinces); (3) WCNRDP (including all the country); (4) SDP-YR (covering 31 provinces); (5) SDP-TN (including 13 provinces); (6) SCP Beijing and Tianjin; (7) PICLD (covering eight provinces); (8) WCRP; (9) FIBRP (covering 18 provinces). Over the period 2010-2050, 13 million ha of new plantations are planned to be established by undertaking large-scale afforestation of barren and arid lands in western China (SFA 2009, Xu et al. 2012, Zeng et al. 2015, Shi et al. 2016). To establish the plantations, China is mostly following the unified Brazilian and Chilean model which developed monocultural stands to facilitate higher timber quality and production (Zhang et al. 2015). The Chinese government provided loans and subsidizes for forest projects to expand the area under plantations. Over 40% of these loans were used to establish high-yielding and fast-growing timber species, and these species facilitated Chinese afforestation technology and turned into a productive force (Yang et al. 2010, Farooq et al. 2019a). Establishing plantations also improved the administration of forest production, which effectively boosted the forest industry (Zhang et al. 2010, 2015).

The contribution of these plantations in terms of pulp and paper production will depend on the suitability of ecological conditions at plantation sites and whether these plantations will reach their full potential without being damaged from any disease or insect attack (Barr & Cossalter 2004). Up to date, some plantations are claimed to be inefficient in enhancing ecological and economic benefits. Overall, these plantation programs have been relatively successful in significantly reducing soil erosion and flooding, in particular the multi-species stands around the upper reaches of major rivers (Zhang et al. 2010, Xu 2011). Moreover, logging was banned entirely in environmentally sensitive areas (Zhang et al. 2015).

Ecological effects of plantations

Along with many positive impacts associated with the expansion of timber plantations (such as the decreasing pressure on and the reduced degradation of natural forests – Pirard et al. 2016), plantations also have some direct adverse ecological effects. For example, even-aged and monoculture plantations over the successive rotations can result in loss of soil nutrients and suitable habitats for taxa living in natural forests (Ma et al. 2000, 2007, Lin et al. 2001, Erskine et al. 2006, Larjavaara 2008, Chen et al. 2009, Hartmann et al. 2010, Xu 2011, Liao et al. 2012, Zhou et al. 2015). Also, these forest stands may alter soil physiochemical, biological properties, and affect water resources (Scott 2005, Stenert et al. 2012). In a study, Yang et al. (1998) stated that, the soil nutrient, microbes, and bio-

Tab. 2 - Dominant softwood and hardwood species in the plantation forests of China.

Group	No	Species	Common Name	Family	Origin	Planting material	Typical Height (m)	Area of Cultivation
Softwood species	1	*Cunninghamia lanceolata*	Chinese fir	Cupressaceae	Native	Seed/Seedlings	15-30	Predominantly in Southern China
	2	*Pinus massoniana*	Masson pine	Pinaceae	Native	Seed/Seedlings	25-40	Predominantly in Southern China
	3	*Larix spp.*	Dahurian larch	Pinaceae	Exotic	Seed/Seedlings	20-45	Liaoning, Heilongjiang, Sichuan, Henan, and Hubei
	4	*Pinus tabuleaformis*	Manchurian red pine	Pinaceae	Native	Seed/Seedlings	20-30	Most parts of China, except for Liaoning
	5	*Cupressus funebris*	weeping cypress	Cupressaceae	Native	Seed/Seedlings	20-35	Southwestern and central China
	6	*Pinus elliottii*	Slash pine	Pinaceae	Exotic	Seed/Seedlings	18-30	Primarily in Pearl and Yangtze river valleys
	7	*Pinus yunnansis*	Yunnan pine	Pinaceae	Native	Seed/Seedlings	20-40	Yunnan, Sichuan, Guizhou, and Guangxi
	8	*Pinus taeda*	Loblolly pine	Pinaceae	Exotic	Seed/Seedlings	30-35	Primarily in Pearl and Yangtze river valleys
	9	*Pinus sylvestris* var. *Mongolica*	Mongolian Scotch pine	Pinaceae	Exotic	Seed/Seedlings	≤ 35	Northwestern China
	10	*Pinus koraiensis*	Korean pine	Pinaceae	Native	Seed/Seedlings	15-30	Northeastern China
Hardwood species	1	*Populus* spp.	Poplar	Salicaceae	Exotic	Seed/Seedlings/ Cuttings	15-50	All over the China
	2	*Eucalyptus* spp.	Eucalyptus	Myrtaceae	Exotic	Seed/Seedlings	10-60	Guangdong, Hainan, Yunnan, Fujian, and Guangxi
	3	*Robinia pseudoacacia*	Locust	Fabaceae	Exotic	Seed/Seedlings	12-18	Cultivated in all of China except Hainan and Xizang
	5	*Hevea brasiliensis*	Pará rubber tree	Euphorbiaceae	Exotic	Seed/Seedlings	≤ 43	Fujian, Guangdong, Guangxi, Hainan, Taiwan and Yunnan
	6	*Paulownia* spp.	Paulownia	Paulowniaceae	Native	Seed/Seedlings	≤ 35	All of China. predominantly in Southern China
	7	*Betula* spp.	Birch	Betulaceae	Native	Seed/Seedlings	≤ 20	Predominantly Northeastern China

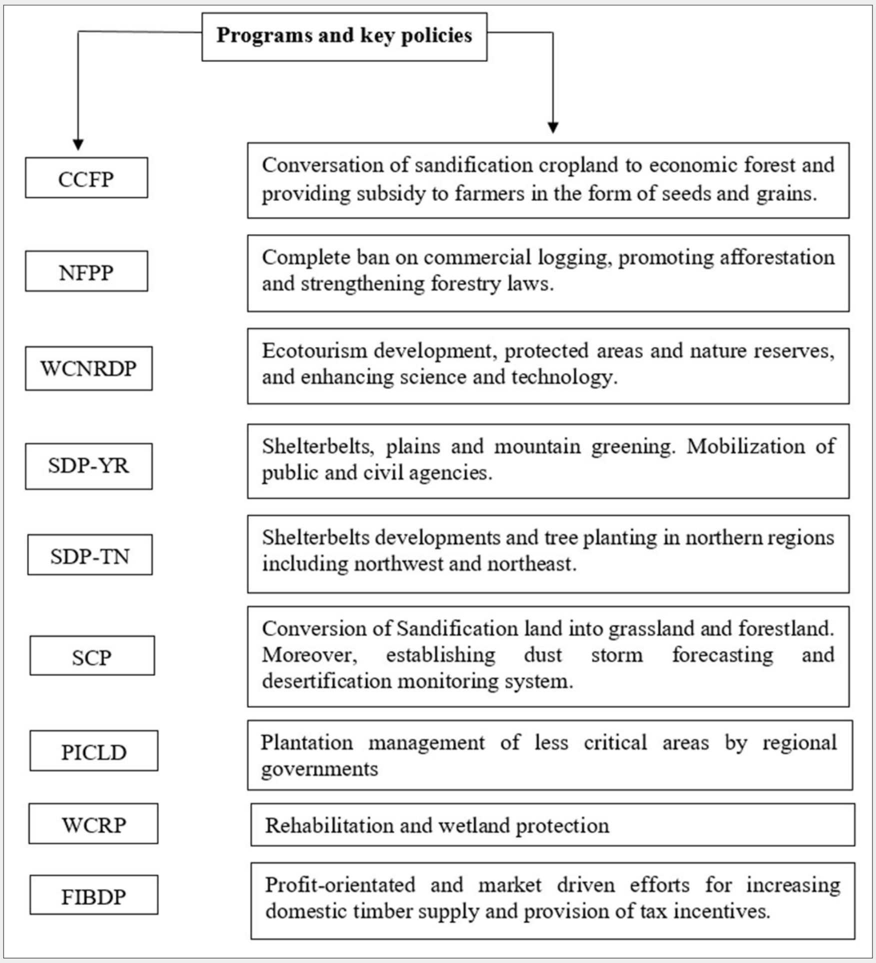

Fig. 5 - Priority plantations forestry programs of China for various regions in the last two decades and critical policy measures associated with them (for abbreviations, see the main text).

chemical activities of total and rhizosphere soil in a plantation forest were largely affected compared to the natural forest of *Castanopsis kauakamii* in Xinkou, Sanming city, Fujian province, China. Their results showed that the soil nutrients variability and enzymatic activity, the abundance of soil microbiota, biological activities, and soil physiological monoids in the rhizospheric and total soil profile of *Castanopsis* plantation were lower than those of the natural stands. Moreover, in plantation stands, the depletion of soil available nutrients was observed (Yang et al. 1998).

Intensive management such as clear-cutting and successive rotations (Ma et al. 2000, Zhou et al. 2015, 2016), results in low structural complexity of plantations, which raises concerns about the reduction of local diversity, water table level and soil nutrient stocks. The majority of plantations harvested at economic optimum rather than at biological maturity can develop extreme nutrient deficiencies, affecting nutrient cycling and long-term productivity (Liu et al. 2018). For example, *Eucalyptus* is one of the main species planted in southern China with successive rotations (monoculture), being extremely beneficial both socially and economically. *Eucalyptus* absorbs nutrients and water quickly during its growth compared to other plants, resulting in a quick reduction of nutrients in the soil and causing water inequity (Bao & Jiang 1994). On the contrary, the establishment of *Eucalyptus* plantations does have positive impacts on reducing soil erosion due to the rainfall extreme events (Zhao 1988, Zhou et al. 2002). Besides, over-fertilization reduces understory vegetation and groundcover diversity (Evans 1976, Wang et al. 2010, Liu et al. 2018). Furthermore, the introduction of exotic species and single-layered plantations can make these stands susceptible to insects and diseases (Hu et al. 2006, Larjavaara 2008, You et al. 2015).

Plantation forests can also be the cause of local extinction of various species (Pereira et al. 2012) by homogenizing the stand pattern and structure (Araujo et al. 2010, Rundel et al. 2014), thus favoring invasive species (Martin et al. 2012). On the opposite, some researches showed that plantations provide ecosystem services and promote the conservation of biodiversity similarly to natural forests (Carnus et al. 2006, Brockerhoff et al. 2013), by maintaining the native flora (Abreu et al. 2011) and fauna (Carrara et al. 2010). Focusing on the wood provision, plantations actively contribute to regulating the social ecosystem services, especially through carbon sequestration and recreation. The adverse ecological influences of plantations have been primarily attributed to improper management. Fast-growing species absorb a large amount of nutrients from the soil to maintain rapid growth, however, trees also produce nutrients through photosynthesis. Much of the nutrients absorbed from soil or produced in leaves return to the soil through dead leaves and branches. Therefore, a steady nutritional balance of soil can be kept under correct management, for example by avoiding clear-cutting practice, complete plowing and burning, and residue removal. These practices are often blamed for site degradation, which results in low growth and productivity (Bhardwaj et al. 2014, Dias et al. 2015, Zhou et al. 2016, Farooq et al. 2019a).

When plantations replace other productive land uses, such as agriculture, they have usually considered the "lesser evil" among environmentalists (Brockerhoff et al. 2008). In support of this statement, Stephens & Wagner (2007) showed that when prior land use was considered in the comparisons, plantations host a greater diversity than the former land use. However, substantial work is required to test whether plantations meet a broader spectrum of sustainability criteria. If, in the future, harvesting in the natural forests has to be reduced and replaced by plantations, extensive research is needed on multifunctional uses of plantation forests (Liu et al. 2008).

Plantations offer important ecological benefits. Stands established keeping in view the soil type, topography, climatic conditions, and species, are recognized for their significance for sustainable production, improved soil and water quality, salinity mitigation, ecosystem services, and biodiversity benefits (Fox 2000, Zhou et al. 2002, Li et al. 2012); however, negative effects on environmental quality after the establishment of industrial plantations, especially on soil and water, is also reported (D'Amato et al. 2017). Due to the general perception of excessive water consumption, forest plantations and their possible impact on water resources have always been the subject of heated discussions. For example, *Eucalyptus* plantations have been often criticized for their high water consumption compared to other species, as it has been shown by past studies. Contrastingly, the results of other studies on water balance, water use efficiency, transpiration rate, and interception losses, proved that *Eucalyptus* does not consume more water per unit of produced biomass compared to any other forest species, and even exhibits superior water use efficiency (Zhao 1988, Zhou et al. 2002, Whitehead & Beadle 2004, FAO 2011). Moreover, plantations reduce soil erosion, thus reducing run-off (Lima et al. 2012). Based on the this positive and encouraging evidence, plantations can also be recommended for soil and water conservation (Lindenmayer et al. 2006, Evans 2009).

Measures to improve forest plantations

(1) The development of high-yielding and fast-growing timber plantations should be based on experimental evidence. Site-specific experimental trials and a broader dissemination of optimized silvicultural techniques for various species can lead to extensive and quick improvements in stand productivity (Freer-Smith et al. 2019). The quality of plantations can be enhanced by gaining evidence from different scientific disciplines. For example, close attention should be paid to provenance and clone testing in small-scale forestry and to high-performing clones in terms of wood yield, matching the species to the site and considering the mortality of the species at each specific site (Freer-Smith et al. 2019). Field testing of nursery results should be implemented because sometimes the same provenances could be unsuccessful at different sites. Moreover, the lack of quality seeds combined with poor information on the adaptability of different species to different environmental conditions can also result in potential losses of yield and economic value.

(2) Due to short rotations and the small dimension of roundwood, timber obtained from plantations is often considered inferior compared to natural forest timber. Developing new and applying best-practiced wood engineering and processing techniques can improve the quality of plantation wood products. Extending the rotation cycle and/or optimizing planting density and tree spacing under natural conditions can improve stand structure over a long period (Lin et al. 2001, Li et al. 2017). However, it is still unclear which silvicultural methods are the most suitable to promote structural diversity in plantations.

(3) Globally, exotic species have been purposely introduced for economic or biological control purposes. A frequent outcome of these introductions is the extinction of the exotic species; however, when the exotic species adapt to the new environmental conditions, different effects are expected. Interactions between native and exotic species could result in a displacement and competitive exclusion of the native species. In some cases, native and exotic species may reach an equilibrium where resources are abundant, and the competitive interactions between them allow for local survival of both native and exotic species. Ehrenfeld (2003) stated that exotic plant species could enhance Nitrogen (N) availability, alter N fixation rates, and produce litter with higher decomposition rates than co-occurring natives, increasing net primary production and biomass; however, the opposite patterns can also occur. In some cases, a given species has different responses at different sites, suggesting that environmental factors and soil type may determine the magnitude of ecosystem-level impacts. On the contrary, Corbin & D'Antonio (2004) reported that exotic species could affect soil N stocks either by fixating atmospheric N or increasing N loss rates. In the latter case this could interfere with restoration efforts, though uncertainty still exists about the environmental restoration carried out by limiting or increasing exotic species (Abella et al. 2012).

(4) At the stand level, thinning and mixed planting may greatly enhance species and structural diversity of the stand, leading to size differentiation of trees and partly randomizing the initial regular pattern. Although both thinning and mixing promote structural diversity, thinning is expected to achieve the goal quicker because it directly manipulates the stand structure, thus accelerating the stand development (Li et al. 2020).

(5) Monoculture, repeated planting, short rotations and clear-cutting can directly threaten plantation sustainability (Minghe & Ritchie 1999, Widenfalk & Weslien 2009, Wang et al. 2010, 2017). By contrast, the complex structure of the mixed forest may favor the productivity and the conservation of biodiversity (Erskine et al. 2006, Forrester et al. 2006, Zhang et al. 2012, Grossiord et al. 2013, Mayoral et al. 2017, Dong et al. 2018, Wu et al. 2018, Zemp et al. 2019). The above-mentioned studies infer that the deficiencies of monocultured plantations may be remedied by choosing complex and mixed cultivation (Mason et al. 2007). Establishing and maintaining mixed forests may promote indigenous forest species and preserve biodiversity at the landscape level. Moreover, clear-cutting and burying of residues should be avoided, while proper thinning and longer rotation cycles should be encouraged (Selvaraj et al. 2017, Farooq et al. 2019a).

Fruitful ecological restoration and progressive projects can attain both environmental and financial goals simultaneously (Tallis et al. 2008, Wunder et al. 2008, Wendland et al. 2010). In light of the aforementioned studies, we stress the importance of conducting an efficient forest management in plantations. Further, the concept of forest cultivation and management is dynamic, and should promote landscape heterogeneity, the maintenance of complexity, species diversity, and ecological functions. Forest cultivation needs to balance economic, environmental, and cultural principles, in order to achieve a sustainable production. Compliance with the aforementioned principles promotes the maintenance of ecosystem services and biodiversity for the future generations.

Additionally, various activities such as incentive policies, rightful ownership, clarity in structures, land availability, and social impacts of plantations require extensive monitoring. The establishment of plantations should be market-oriented and financial resources should be mobilized through multi-channels. Furthermore, data inaccuracies about plantation area management must be corrected to provide an accurate picture for private and public policy setting.

Conclusions

With the implementation of programs for the protection of natural forests, China's wood supply sources are shifting from natural forests to plantations, the impact of which is mostly dependent on implementing sustainable strategies and management practices. However, extensive forest cultivation presents various challenges, such as diminished soil fertility, disease and pest attacks, decreased biodiversity, and reduced productivity. The sustainability of plantations will require diligent and watchful management of soils and stand structural diversity. Plantations should be established on the barren land, thus improving the ecological conditions of planting areas and increasing local biodiversity. This can be done only by understanding the ecological context of forest plantations in the broader spectrum. Although there is an increasing literature on plantations and their impacts, there is still a need for further studies on soil microbial and enzymatic activities that widen our understanding of the long-term effects of plantations. Because of the complexity of forest ecosystems in China, more species- and site-specific studies are required in order to provide the ecological knowledge needed to increase the sustainability of cultivated forests.

Declaration of competing interest

Authors declare no conflict of interest exists.

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