

**Characteristics of the  
Crop-Paulownia System in China**

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## Abstract

This paper reviews the crop-paulownia (*Paulownia elongata*) system in China. We focus on the system's characteristics and the impact of government policies on its development. When paulownia is intercropped with winter wheat, their different growth periods and root distributions result in more efficient use of water and other limited resources. In addition to timber production, paulownia trees on cropland enhance the microclimate and therefore improve wheat yield and quality. Intercropping also stabilizes farm income and reduces farm risk by diversifying agricultural activities and providing windbreaks and shelters that stabilize crop production over time. China's rural reform initiated in 1978 is a major source of the rapid development of the system in the past decade. The reports of the great performance of the crop-paulownia system, along with its high tolerance to natural conditions, are likely to make it attractive and adoptable to other countries.

## **Introduction**

With 22 percent of the world's population and only 7 percent of the earth's arable land, China has developed numerous agroforestry systems to maximize the production of both food and timber from every parcel of arable land. One key example is the crop-paulownia (*Paulownia elongata*) system, in which paulownia trees are intercropped with field crops such as wheat. *Paulownia elongata* is a fast-growing tree species with vegetative propagation and high tolerance to natural conditions. The average height and canopy radius of a 7-year-old paulownia tree are about 8 to 12 meters and 3 to 5 meters in Henan Province (Zhao et al. 1986). Paulownia crown is quite sparse because it generally develops different crown layers (Wu 1991). The crop-paulownia system developed rapidly in China during the 1980s. In 1989, 3.18 million hectares in the North China Plains were under intercropping of field crops, paulownia, and some fruit trees (Wang 1990). In Henan Province, the area of crop-paulownia system increased from 0.40 million hectares in 1983 to 1.72 million hectares in 1986. China's annual output of paulownia timber was about 2 million cubic meters in 1987 and is expected to exceed 10 million cubic meters by the mid-1990s (Hou 1988). Such rapid development of an agroforestry system rarely has been reported in other regions of the world. This paper reviews the development of the crop-paulownia system in China, focusing on its characteristics and the impact of government policies on its development.

## **Development of the crop-paulownia system in China**

The development of the crop-paulownia system in China is significantly concentrated in the middle and lower reaches of the Yellow River, a region with serious soil erosion, drought, and flood problems. Every year, an average of 1.6 billion tons of sand and mud is washed into the lower reaches of the Yellow River, 37.6 kilograms for each cubic meter of water (Li 1990). In response, the Chinese government began water and soil conservation programs in this region in the mid-1950s. After two decades of massive efforts focused primarily on engineering measures such as the flood-control projects along the river, biological strategies including agroforestry began to be strongly recommended in the late 1970s and have been emphasized ever since. In addition to direct state

investment in research and large conservation projects, many government programs involving technical advice and environmental education have been designed to promote the development of these biological measures.

The crop-paulownia system was first developed in western Henan Province in the late 1970s and has expanded quickly in Henan and several other provinces in China since the early 1980s. Table 1 and Figure 1 illustrate the areas and geographic locations of the major regions of the crop-paulownia system in 1986. Although no official data are available after 1986, the system has expanded continuously in these major provinces and others such as Gansu and Sichuan (Hou 1988).

#### **Characteristics of the crop-paulownia system**

The performance of any agroforestry system is determined by the biological relationships among the components within the system, combined with other factors outside the system. In addition to the high market value of paulownia timber, in the wheat-paulownia system the different growth periods and root distributions of the two plants are key factors of the system's attractive performance in China.

The growth periods of paulownia differ from those of most field crops. When winter wheat is grown from seeding to the tillering stage, paulownia is in the rest period, implying no significant competition between the two plants for water and other resources. The only time in which paulownia has a significant negative effect on wheat growth is in the last month before wheat is harvested. In this period, the canopy limits the amount of light reaching the ground and thereby affects wheat growth. In a study by Zhao et al. (1986), however, in which seven-year-old paulownia trees grew at a density of 60 per hectare, the yield reduction under the canopy was more than offset by the gains from the areas not under the canopy (see Table 2).

Unlike the shallow-rooted wheat grown beneath it, paulownia has a root system that is mostly 40 centimeters below the soil surface (Zou and Sanford 1990). Paulownia's long roots use water from deep soil layers. Wei (1986) reported that, for a paulownia tree 7 to 10 years old, 80 percent of its roots are distributed in a layer 40 to 100 centimeters below the soil surface, 10 percent is in a layer

more than 100 centimeters below the soil surface, and only 10 percent is in the upper 40 centimeters of the soil profile. From another point of view, 30 percent of its roots lie within a radius of 2 meters from the tree trunk, and more than 98 percent are within 5 meters from the trunk. This root distribution is a key factor in explaining why only 20 percent area of the intercropped field had a reduced wheat yield (see Table 2). Through windbreak and shelter effects, paulownia trees on cropland significantly enhance the microclimate for crops. Wei (1986) reported that, while winter wheat was in the seed-filling period, paulownia trees in a field in western Henan Province reduced windspeed by 45 to 50 percent, increased relative humidity by 5 to 17 percent, reduced water evaporation by 15 to 30 percent, and increased water content in the tillage layer by 5 to 15 percent. Although we have found no data on paulownia trees' impacts on soil erosion in China, the reduction of windspeed and water evaporation, along with their role in reducing the energy of raindrops, is expected to reduce soil erosion because soil erosion is positively related to windspeed and the energy of raindrops, and negatively related to soil wetness (Beasley 1978).

There are several ways the crop-paulownia system has significantly improved farm production and profitability in China, including increased crop production, improved crop quality, more salable products, and reduced farm risk. Many crops exhibit positive responses to the protection by paulownia trees when tree density is within a certain range. Table 3 summarizes the results of field research in Henan and Shandong provinces in the late 1970s and the early 1980s (Wei 1986). With tree density from 45 to 120 per hectare, winter wheat and millet showed increased yields, ranging from 10 to 38 percent. These results are consistent with Kort (1988). Summarizing research in 14 countries, Kort suggested that winter wheat, barley, millet, alfalfa, and many other crops exhibit positive yield responses to windbreak protection, ranging from 6 to 99 percent.

A comparison analysis using the survey data of Zhao et al (1986) in western Henan Province identifies the factors contributing to increased crop production and expect net revenue (see Table 2). All the surveyed paulownia trees are seven years old and were planted 60 per hectare. Paulownia competes with winter wheat grown under its canopy for resources, significantly reducing the wheat

yield under the canopy (about 20 percent of total area cropped). Wheat yield in the remaining area, however, increased significantly due to the protection by the paulownia trees. The yield reduction under the canopy is more than offset by gains from the area not under the canopy, and the overall wheat yield increased 17.26 percent. The weight per thousand grains exhibits a similar relationship. Volume of paulownia timber, another highly demanded output of the wheat-paulownia system, is also reported in Table 2.

Table 4 summarizes estimated revenues, production costs, and net revenues of the two systems. The figures for wheat production in both systems are annual ones, while the paulownia cost is the simple average of seven years. Net expected revenue of paulownia timber is estimated by using the timber volume in Table 2 and its market price. Because of data limitations, the value of paulownia leaves and branches is unaccounted and no depreciation factor is used in the estimation. The expected average per hectare annual net revenue of the wheat-paulownia system is more than three times that of the wheat production system without trees.

In addition to the beneficial effects on crop yields, intercropping with paulownia trees improves crop quality by protecting crops from dry wind and other natural calamities. Zhao et al. (1986) reported that the gluten content, germination percentage, and protein content of winter wheat from the intercropped field increased by 2 to 3.7 percent, 0.5 to 1.2 percent, and 0.2 to 0.6 percent.

Besides crop and timber production, the crop-paulownia system produces a significant amount of paulownia leaves and branches, which are also profitable for farmers. Paulownia leaves that fall in the autumn can increase soil nutrients and organic matter, thereby reducing off-farm inputs. For a paulownia tree 8 to 10 years old, the average amount of 100 kilograms of fresh leaves, containing 2.8 to 3.0 percent nitrogen and 0.41 percent potash, is a significant source of organic matter and soil nutrients. Paulownia leaves are also good fodder for hogs (Wei 1986). Paulownia branches are a ready source of household energy.

In addition to its environmental value, one major motivation of agroforestry is to stabilize farm income and reduce agricultural risk by diversifying farm activities (Godoy and Feaw 1991). As a

long-term crop for timber production, paulownia interspersed with field crops is an additional farm activity and directly increases farm income (see Table 2). As trees in general, paulownia trees on cropland provide windbreaks and shelters, which allow the cultivation of some vegetable and fruit crops that otherwise would be difficult or impossible (Schaefer 1989). For example, both yield and quality of plum, tomatoes, and strawberries, which are extremely sensitive to wind, can be improved through the natural windbreaks, preventing sandblasting, blossom destruction, discoloration, and premature fruit drop (Schaefer 1989). Moreover, after a certain growth period (6 to 10 years), paulownia trees can be marketed in case of a lean crop year or a tight financial situation. This is similar to a special form of self-insurance and is especially important for Chinese farmers because market farm insurance is unavailable in most areas. In several counties such as Luyi in Henan Province, the average paulownia timber volume per person was about one cubic meter in 1989, and had a market value equivalent of about one-third of a local farmer's average annual income.

#### **Impacts of government policies on agroforestry development**

Of the factors affecting the development of agroforestry in China, one cannot underestimate the critical influence of government policies. Although the crop-paulownia system has been practiced in China for centuries, its rapid development in the past decade is due largely to the successful rural reform dating from 1979. Before the reform, the government's extremely high priority of food production allowed farmers to grow only food crops and a few industrial crops such as cotton. Afforestation was limited to "four-sided" (village, road, ditch, and river sides) planting with poor management. China's rural reform replaced the commune system with the household production contract system and allowed peasants to make their own production decisions.

Several policies and programs contain key incentives that have significantly stimulated the development of the crop-paulownia system. First, although land is still owned by the state or collectives, the land contract (15 to 25 years) is long enough for peasants to grow paulownia as a long-term crop with high expected economic returns. Second, the extension programs provide training classes and technical advice that strongly encourage peasants to adopt the system. Third,

government subsidies in purchasing paulownia saplings in many areas reduce the cost of adopting the system. Fourth, the decentralization of marketing systems for farm products, including timber, has resulted in higher prices for these products. China's extremely limited timber supply and steady demand growth have made planting paulownia trees an alternative farm activity with high expected profit.

#### **Projections for the crop-paulownia system**

Environment conservation and timber production are the major motivations of the Chinese government for promoting agroforestry systems. But since food self-sufficiency has always been a high priority of China's agricultural policies, any agroforestry system for China must entail no significant reduction in food production. The high economic returns and increased food production of the crop-paulownia system make the system attractive to both farmers and policymakers. China's continuing economic reform and the increasing demand for paulownia timber should further the steady growth of the nation's crop-paulownia system.

As a new science but an age-old practice, agroforestry has been adopted by many countries such as Haiti and Kenya. The development and study of agroforestry systems, however, have occurred primarily in extensive agricultural regions such as tropical areas with low land productivity (e.g., Nair 1989; Stepler and Nair 1987). The success of the crop-paulownia system in China suggests that agroforestry is also an adoptable approach in heavily populated areas with extremely limited arable land. This experience is highly relevant to other countries with limited arable land and shortages of both food and timber. The great performance and high tolerance of the crop-paulownia system in China are likely to make the system attractive and adaptable to other countries.



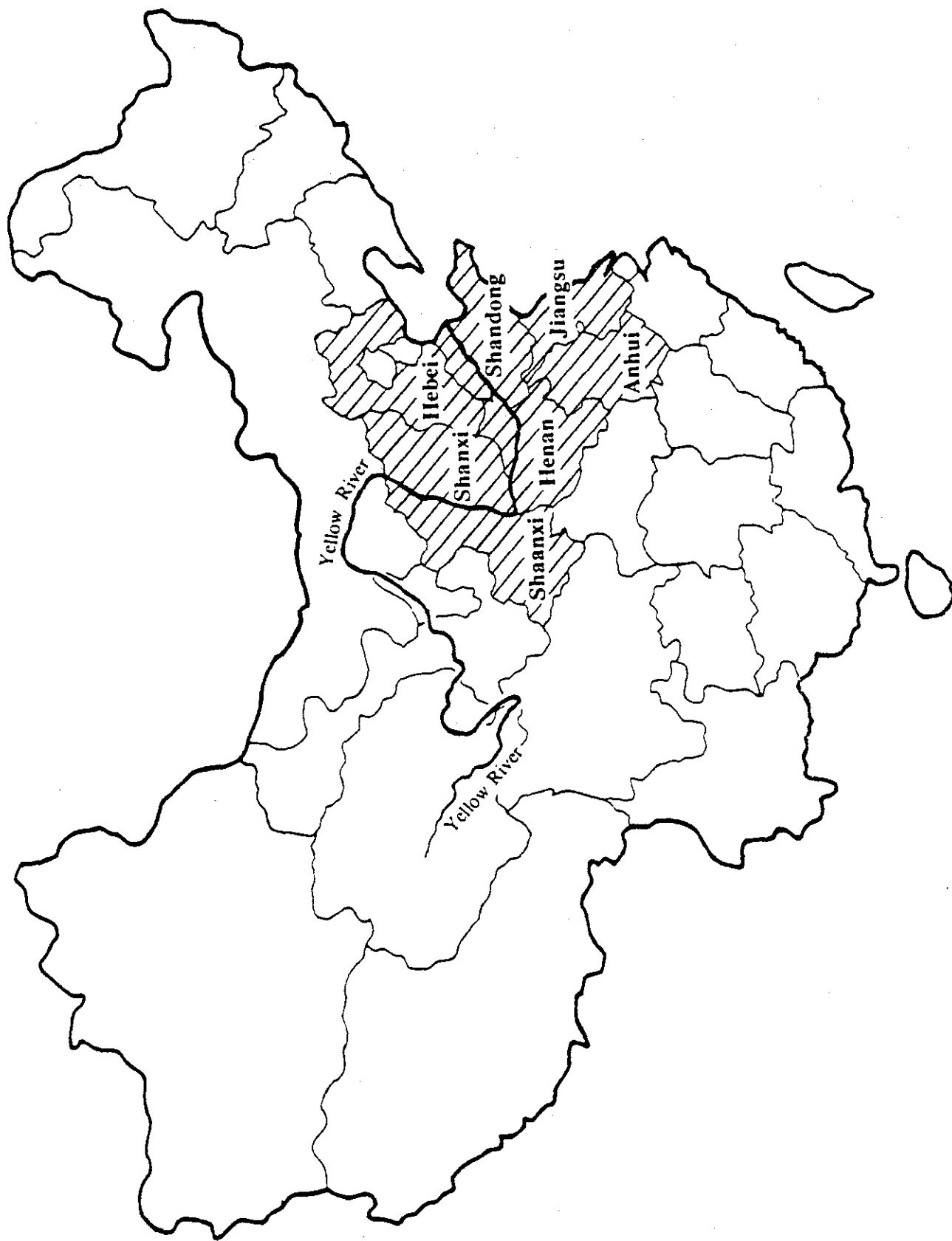


Figure 1. Major regions of the crop-paulownia system in China

Table 1. Areas of the crop-paulownia system in China

Province	Total arable land (1,000 ha)	Crop-paulownia system	
		Area (1,000 ha)	% of total arable land
Henan	6,998.9	1,718.7	24.56
Shandong	6,924.3	863.3	12.46
Hebei	6,576.5	162.0	2.46
Anhui	4,396.9	139.3	3.17
Shaanxi	3,562.7	80.0	2.25
Shanxi	3,719.3	22.7	0.61
Jiangsu	4,579.8	20.0	0.44

Source: China's Forestry Yearbook of 1949-1986.

Table 2. Outputs of wheat and wheat-paulownia systems in Henan, China

System	Wheat yield (Kg/ha)	Weight per 1,000 grains (g)	Timber volume	
			(M <sup>3</sup> /tree)	(M <sup>3</sup> /ha)
Wheat	2,113.5	36.2		
Wheat-Paulownia				
Under canopy (20% area)	1,567.5	34.3		
Not under canopy (80% area)	2,706.0	38.1		
Average	2,478.3	37.3	0.1537	9.222

Source: Zhao et al. (1986).

Table 3. Yield increases of the crop-paulownia system in China

Crop	Age of trees (Years)	Tree density (Trees/ha)	Yield increase (%)	Location (County, Province)
Wheat	7	45-75	10-38	Lankao, Henan
Wheat	7-14	45-90	10-33	Lankao, Henan
Wheat	13	105-120	13-15	Changge, Henan
Wheat	8-10	45-75	10-20	Minquan, Henan
Wheat	10	45-60	10-25	Shandong
Millet	7-14	45-90	20	Lankao, Henan

Source: Wei (1986).

Table 4. Net revenues of wheat and wheat-paulownia systems in Henan, China

System	Revenue	Cost	Net revenue
--- Yuan per hectare per year ---			
Wheat	625.60	465.00	160.60
Wheat-paulownia			
Wheat	723.66	465.00	258.66
Paulownia	337.68	13.71	323.97
Total	1,061.34	478.71	582.63

Source: Zhao et al. (1986).



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