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AGROFORESTRY IN CHINA - AN OVERVIEW

by

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Introduction

China is a vast country. Its land mass covers about 9,602,700 km^2. Of this about 100,000,000 hectares are arable while another ~~115,000,000~~ 11,500,000 are forested. The country has a population of well over one billion people, eighty percent of whom are peasant farmers living in rural villages. Given the size of the population and the limitation of arable land a villager in China has less than 0.13 ha land for himself and this availability shrinks further to less than 0.03 ha in densely populated areas. Similarly in terms of wood availability, the standing volume of timber is about 10.3 billion m^3 or averaging about 10 m^3 per Chinese person.

China launched its four modernisation programmes about a decade ago. This has resulted in increased industrialization activities with a consequent increase in demand for timber and energy. This demand has led to an increasing pressure on land. Rapid and over exploitation of forested lands has led to increased soil erosion, increased run off, siltation of the rivers, flooding and droughts. The most heavily eroded regions (about 280,000 km^2) lie in the middle reaches of the Yellow River at the Loess plateau where the forest cover is less than four percent. The silt flowing through the Sanmen Gorge of this river amounts to about 1.6 billion tons per year. This silt is estimated to raise the river bed of the lower reaches by 10 cm annually. The siltation is also known to affect the storage capacity of the reservoirs along the river.

Investigations carried out on seventeen of the twenty biggest reservoirs along the Yellow River Basin indicate that they receive a deposit of about 6 billion m^3 or 60 percent of their total storage capacity. It is also estimated that the run off carries with it approximately 30 million tons of nitrogen, phosphorous and potassium. This type of equally alarming situation also exist along the Yangtze River basin, China's ~~second~~ biggest river. Here the silt from soil erosion amounts to amount 640 million tons per annum.

It is obvious that for China to maintain its momentum of modernisation in order to meet the aspirations of her people urgent measures need to be adopted to enhance land utilisation. This should also include the greening China's 1,280,000 km of deserts in the North western region as well as preventing further desertification. It is estimated that about 6,700,000 hectares of farmland and a similar area of pasture land over 200 counties in this region is vulnerable to calamitous sandstorms. For instance desertification in the Nei Menggu Autonomous Region has doubled from 7,330,000 ha to about 10,670,000 ha between 1960 and 1977.

The country's timber supply is also very short of satisfying demand. Partly indiscriminate exploitation of forest resources in the past, for wood, fodder and energy, has left vast areas of China depauperate of vegetation. Urgent measures are needed and being taken to reforest the country. Annually an average of

3 million ha of land is afforested, still the country is dependant to a large extent on imported timber and pulp to meet domestic demand.

To ameliorate this increasingly difficult situation, the Government of the People's Republic of China has been taking a series of measures. These measures are meant to help arrest the irreversable effects of soil erosion, siltation, flooding and desertification. Policies have been designed to enhance the farmers' ability to produce more food, to put the land to multiple use including the planting of forest trees that are multipurpose; to afforest in denuded and wasted lands that lack agricultural potential, to expand forested area for purposes of conservation, shelter, catchment and arrest desertification.

Part of this policy also lays emphasis on combining agricultural and forestry crops together. Chinese farmers and scientists are working together to identify appropriate species combinations, management techniques, agronomic practises and protective measures to increase the yield of the land. In China such plantation technologies go under a variety of names. These include terms like 'stereoscopic agriculture', 'stereoscopic forestry', 'multiple ecological system of agriculture and forestry'. All of these terms are synonymous to 'agroforestry' and the terms are meant to name a farming system or an "artificial" agroecosystem serving certain ecological and economic purposes. Such systems are also

considered to temporarily or permanently combine forestry (including arbor or shrub and timber or economic forests) with agriculture or livestock according to certain model on the same management unit or land. Its aim is to provide the best ecological and economic benefits to the farmer.

Even if the terminology used in China is different the practice of this kind of plant culture is not different to the "sustainable land management system which increases the yield of the land, combines the production of crops (including tree crops and forest plants) and/or animals simultaneously or sequentially on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population" (King and Chandler, 1978)[1].

There is enough evidence in literature to suggest that forest trees and agricultural crops can be grown together without deterioration of the site. For example the taungya system as described by Blanford (1958)[2], many ancient cultural practices where some societies simulate forest conditions on their farms in order to obtain the beneficial effects of forest structures, and the evidence of Fisher (1976)[3] and others, that mixed cropping of annual crops is

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[1]King, K.F.S. and Chandler (1978) The Wasted Lands, ICRAF, Nairobi.

[2]Blandford, H.R. (1958) Highlights of One Hundred Years of Forestry in Burma. *Emp. For. Rev.: 37(1).*

[3]Fisher, N.M. (1976) A Limited Objective Approach to the Design of Agronomic Experiments with Mixed Crops. In Intercropping in Semi Arid Areas Ed. Morys, J.H., Ker A.D.R. and Campbell, M. IDRC Ottawa.

often more efficient means of utilizing land area than pure stands. The rest of this paper describes a few Chinese models of agroforestry.

I. History of Agroforestry

One form or another of agroforestry has been practised in China since ancient times. During the Han Dynasty (206 B.C. - A.D. 220), administrators have been recommending the development of forests together with the raising of livestock and crops according to different site conditions. Many successful agroforestry systems have been in practice, some of which have developed very fast throughout the country since new China was established. It has been shown through scientific research and farmers' practice in China and elsewhere that agroforestry systems have many advantages with bright developing future.

In the Northwest, North and Western part of the Northeast of China (abbreviated to 'Three Norths'), a program of developing large-scale shelterbelt system has been started, known as the 'Green Great Wall' program. Its objectives include rehabilitation of wasteland, development of vegetation for the control of sandstorms, as well as soil and water erosion control through large-scale afforestation and grassland development. It started as an agroforestry system in 1978, as perhaps the biggest program in the world. It is scheduled to be completed at the turn of this century. The Government allocated USD 72.2 million during the past seven

years, as a special fund for the development of the shelterbelt system; another USD 243.3 million had been raised from other sources through either state or local channels. During the first phase (1978-85), 12.8% of farmland shelterbelts, 23.2% of dune-fixing forests, 55.3% of soil and water conservation forests and the remaining 8.7% of other types of forests was expected to be established. While planting, establishment of high forests and shrubs was done together with grasslands and large-scale shelterbelts, small patches of woodlands and forest networks were built together. As a result, 6.7 million ha of farmland and 3.4 million ha of pastures have been put under protection. Soil and water erosion in some of the areas have been partially controlled and the insufficiency of fuelwood partially solved.

Today, there exists an initial system of farmland shelterbelts stretching over 440,000 hectares of thirty-nine counties in the Ningxa Hui Autonomous Region and Nei Menggu Autonomous Region; and, [illegible] hectares in Xinjiang Uygur Autonomous Region. It is reported that areas under the protection of shelterbelts are capable of producing higher crop yields which are superior in quality - yield increases average 16.4% for maize, 36% for soybean, 42.6% for sorghum and 43.8% for millet. In areas with critical problems of soil and water erosion, activities aimed at comprehensively managing small-watersheds have been undertaken. Planting trees and grasses coupled with the building of checkdams, dykes and terraced fields are some of the various forms of control measures instituted over

8.2 million hectares of eroded land. Similarly, in areas with serious problems of strong winds and sandstorms, efforts are being encouraged to rehabilitate them with shrubs so that today, 367,000 hectares are basically fixed, out of which 35,000 hectares have already been brought under the plough.

The plains are centers of agricultural production in China, constituting about 10 percent of the country's total land area or a total of 40 million ha of farmland. Living on these plains are 350 million people. The main forms of agroforestry are:

(a) farmland shelterbelt

(b) intercropping agricultural crops with trees

(c) planting trees around houses, and along roadsides, river banks, etc.

The farmland shelterbelts are usually built together with roads and channels. Their sizes are 6-20 hectares, most of which are narrow-spaced shelterbelts. Statistics show that 643,000 hectares of farmland shelterbelts have so far been built and 10.73 million ha of farmland brought under protection, with systems having produced a large amount of timber and fodder. Such farmland shelterbelts have been widely used in the North and the Northeast of China as well as in parts of the southern subtropical areas.

Several systems of intercropping agricultural crops with trees have been practiced in the plains, over an area of more than two million hectares. The main forms of intercropping agricultural

crops with paulownia in the North of China are: date, fruit tree, willow, false indigo and white mulberry. This type of vegetation can be efficiently used either for control of soil or wind erosion as well as fodder or as organic fertilizer. Intercropping agricultural crops with paulownia trees has been extended over one million hectares of land. In some lower districts of the Yangtze River Delta and Zhujiang Delta, forms of agroforestry such as: forest plus agricultural crops, or, forest plus agricultural crop plus fishing and herbage, are being tried.

Planting trees around houses, villages, along roadsides and rivers is another common type of agroforestry in China's plains. According to statistics, 7.2 billion trees have been planted in the plains, among which 5.8 billion are planted around houses and in villages, with each peasant household having an average of seventy-four trees. The village's area usually amounts to 10-15 percent of the total area of plain land. It can be said that each village is just like a 'village forest farm'. Besides producing certain amount of timber, other associated activities that have emerged are animal husbandry, floriculture, and fishing industry. The peasant is thus managing intensive multiple use of the small area of land around his house. He may derive an income of more than ten thousand Yuan RMB[1] from a garden of less than 0.02 ha ('Garden Economy').

In China's hills and mountain areas, other types of agroforestry is practised as site conditions vary from place to place. Widespread among these practices with a rather long history

[1] USD 1 = 3.7 RMB (approx)

and covering a big area is intercropping agricultural crops with trees such as Aleurites fordii, Sapium sebiferum, Juglans regia, Castanea bungeana, Camellia oleifera, Camellia senensis, Hevea brazilensis, Diospyros kaki, and Fraxinus chinesis. Successful trials have been conducted to plant traditional Chinese medicinal plants such as Panax ginseng in the Northeast, Coptis chinesis var. brevisepala, Amomum villosum, Gastrodin elata in the Southwest; and some edible fungi such as Auricularia uderw, Tremella uderw, Dictyophora indusiata, Lentinus edodes and Pleurotus ostreatus under forests, such as bamboo forest which has shown a great production potential.

Recently, agroforestry as a discipline has been receiving more and more attention in China. It has been studied by many categories of scientists from their respective perspectives, namely - forestry scientists, agriculturists, animal husbandry scientists, hydraulic engineering scientists, agro-meteorologists, ecologists and socio-economists. A workshop on Agroforestry was held by the Ecology Committee under the aegis of the Chinese Society of Forestry in October 1986. More than 500 papers on agroforestry have been published so far on the subject.

Under the Chinese Academy of Forestry, the Forestry Research Institute, the Subtropical Forestry Reseach Institute, and the Tropical Forestry Research Institute all have their own projects in agroforestry, some examples include:

(a) the 'Three North' Shelterbelt System Engineering,

(b) the Plain Farmland Shelterbelt System,

(c) the Intercropping agricultural crops with Paulownia, Chinese date, Aleurites fordii, and

(d) the Cultivation of Dictyophora indusiata under bamboo grove.

Several national forestry research institutes and universities have also participated in these studies. For instance, the Nanjing Forestry University has a project in Lixiahe district of Jiangsu Province, regarding agroforestry multiple ecosystem and pine plantation with tea cropping. The Academy of Sinica studied agroforestry in Yunnan Province - mulberry plantation with fish farming in Zhujiang Delta.

The International Tree Crop Institute, China Office was established in October 1986, the headquarters of which is located at the Chinese Academy of Forestry, Beijing. It will paly an important role in the development of agroforestry in China and in international cooperation in agroforestry.

II. New and Highly Promising Agroforestry Systems

This part of the paper will now elaborate on seven agroforestry systems currently in practice:

1. Intercropping agricultural crops with Paulownia.
2. Intercropping agricultural crops with Chinese dates.
3. Artificial agroforestry multiple ecosystem in Lixiahe flatlands.

4. Multiple layer artificial population in Yunnan tropical area.
5. Forest grass system in West-Northern Loessial Plateau and desert area.
6. Intercropping models in subtropical forest region.
7. Garden type agroforestry.

(1) Intercropping agricultural crops with Paulownia sp.

This system which has been used and expanded in approximately 112 million ha has now become an important cultivation system in flatlands of north China. Paulownia elongata is one of the fastest-growing trees in this region. About 0.5 m^3 volume of timber can be harvested from a ten-year old individual tree. Paulownia possesses some traits which are good for intercropping such as: deep root system (> 40 cm), deploying leaves coming late, and more transparent crown.

In sandy and loamy soil approximately 75% of the root system is found in depths of 40-100 cm as against wheat, millet and maize where root systems rarely go below 40 cm. This simply means that there is minimal competition between trees and crops. On the contrary,because of the deep rooting nature of Paulownia,vertical leachates of fertilizers and water applied to the agricultural crops is available to Paulownia. In drier seasons, Paulownia absorbs underground water from the deeper layers and helps in humidifying the upper layers.

Intercropping of agricultural fields with Paulownia generally seems to enhance the suitability of the microclimate for agricultural crops. Our experiments showed that wind speed was reduced between 21-51%, evaporation rate by about 9.7% in day time and 4.3% in night time, increase in the moisture content of the upper layer of soil by as much as 19.4% and air temperature went up by about 0.2-1°C in winter and down between 0.2-1.2°C in summer. There was also a strong trend at increased yields in agricultural production. Wheat increased between 6-23%, millet by about 20% and maize between 7-17% (Anon, 1976)[4].

Paulownia can be planted in different density spacings (5x10m-5x40m). The tree has played a notable role in alleviation of natural calamity caused by early summer's dry-hot wind and drought; thus ensuring high and stable yields of crops, the economical benefit of which has shown 15-25 percent increase when compared to single stand crops.

(2) Intercropping agricultural crops with Zigyphus jujuba (Chinese date)

This date is a nut tree species peculiar to China, thriving from temperate to subtropical areas. The Yellow River-Huaihe River plain is its centre of distribution. Jujube fruit is rich in vitamin C (380-600 mg/100 g), with level higher than that present in apple. Jujube fruit is quite nutritive, and its flower nectariferous. It is reported that 1500 kg of bee nectar can be collected from one

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[4]Anon (1986): Paulownia in China - Cultivation and Utilization. IDRC Singapore.

hectare of intercropped land. It is an ideal intercropping tree species, for it does not deploy leaves until the first ten-day period of June, and has a thin crown. Intercropping space between two sprouts can be 3-6x6-12 m. Jujube enters into the fruiting stage while it is about ten years old, and the average yield can be 6000 kg/ha. In an intercropping system, mixed planting of the date with wheat results in the increased yield of both. The yield of intercrop wheat can reach 3.8 ton/ha, which is higher than that in a pure stand. As a result, the economical benefit increases by more than 100 percent. The jujube-crops intercropping system has now exceeded 7000 ha of land area.

(3) Artificial agroforestry multiple ecosystem in Lixiahe flatlands. The Lixiahe flatlands lying in the coastal belt receive deposit silt from Yangtze River and Huai River. The total area is 1165 km^2, out of which a major portion has not yet been utilized. It has been demonstrated that models such as forestry plus agriculture, forestry plus agriculture plus fishery, and forestry plus animal husbandry are the most appropriate ways to utilize land resource in this region. The flood resistant tree species Taxodium ascendens and T. distichum are now the most popular tree species planted there. Intercropping crops on forest glades, pisciculture in rivers, ponds and penstock, and growing hydrophilic crops such as fodder and lotus rhizome all sum up to the agroforestry system where one component symbioses with another. Consequently, the ecosystem gets improved and the economical benefit derived increases

by as much as five-fold at some sites when compared with monocrop farming. A ten-fold increase, yield of firewood, has been observed when compared to unexploited wasteland.

(4) Multiple layer artificial population in Yunnan tropical area. At Yunnan Xishuangbanna Centre for Tropical Forest Research, scientists have been able to develop stereo-population models after having studied the ecological and economical profiles of various trees and crops. In this regard, it can be noted that the yields of tea and traditional Chinese medicine are increased. Experiments have indicated that Cinchona ledgeriana, Coffea sps., Rauwolfia yunnanesis and Cinnamomum cassia can grow under crown where the shade density is below 0.7°, and their yield and quality can exceed pure tea plantation and drug plantation. Rubber tree plus tea tree, and rubber tree plus camphor tree plus tea tree are the best patterns. In forest land, the yield of tea increases by an average of 412.5 kg/ha, with the quality being much better. Similarly, the yield of Cinchona ledgeriana planted in rubber tree stand (shade density 0.3-0.7) is also increased. In multiple layer population, the rubber yield of rubber tree is also found to be higher than that from pure rubber stand.

(5) Forest-grass system in West-Northern Loessial Plateau and desert area.

In this area, owing to the arid climate, serious damage occurs to the vegetation cover. There is a shortage of fuelwood, forage and timber. The new policy now is to develop a forest-grass structure

combining high forest and shrubbery with grass, so that soil can be conserved thus maintaining soil fertility, and the problems of lack of fuelwood, timber and fodder attenuated. The main tree species are Elaeognus angustifolia, Lycium furcomanicum, Populus sp., Lamarix chinensis, Canagana korshnskil, Hippophae rhamnoides; and the grass species are Astragalus adsurgens and Medicago sp. These forest-grass patterns are successful both in terms of ecology and economic benefit.

(6) Intercropping model in the subtropical forest region.

The subtropical area is vast in China. There are many types of timber forest and economical forest as well as varied and interesting forms of agroforestry. The latter can be altered following variation of time and shade density of the supertree. For example, China fir is a main timber afforestation tree species; in its first three years of growth, some crops such as corn, potato, bean or peanut can be undersown. When the young forest develops into crown closure, the traditional Chinese medicine such as Coptis chinensis can be planted. Some China fir forests are first mixed with oil tong tree, previous to intercropping with Coptis chinensis, or Amorphophallus rivieri.

To intercrop agricultural crops with tong tree is a rather common practice in hilly areas. Tong tree is planted in level terraced field on the hill slopes at a planting distance of 6-8 x 4 m (340-420 tree/ha), and on the slopes of terraced fields, sweet potato, beans, day lily and melon are grown. The physical and chemical

characteristics of the soils have equally improved due to agriculture measures such as better fertilizer management including returning straw to field as shown in Tables 1a and 1b.

Table 1a. Effects of tong tree-crops intercropping on three soil chemical properties in a tong tree forest (0-20 cm).

Treatment	Organic Matter %	Total N %	Total P %
Before intercropping	1.23	0.041	0.008
Intercropping for 1 year	1.76	0.066	0.011
Intercropping for 2 years	1.99	0.079	0.009
Intercropping for 3 years	2.09	0.097	0.010
Beginning intercropping at 4th year	1.82	0.063	0.011
Beginning intercropping at 5th year	2.10	0.066	0.012

Table 1b. Effects of tong tree-crops intercropping on two soil physical properties.

Physical Property	Before inter-cropping	Intercropping Period (Year) 1	2	3	4	5
Specific gravity (g/cm^3)	1.34	1.120	1.04	0.96	1.01	0.98
Porosity (%)	50.80	50.80	61.90	65.10	63.20	64.30

It has also been found that tong oil yield is increased following persistent intercropping. For example, intercropping crops with tong trees for five years can produce tong oil at the rate of 261 kg/ha, thus showing an increase of 200% when compared to a full stand; simultaneously large quantities of agriculture products are harvested (Table 2). Thus, output value of forest land is significantly raised. In 1981, at Fuyang's Suangjiang village, the income from intercropped forest field raised to USD 474/ha, whereas from unintercropped, the value was only USD 36/ha.

Table 2. Yield of major crops grown in tong tree-crop intercropping system.

Crops	Peanut	Rapeseed	Sweet Potato	Potato	Water Melon	Daylily
Yield (kg/ha) (area in stands)	810.0	428.2	10125.2	9999.0	21600.0	322.5

In the subtropical bamboo region, the peasant is accustomed to collecting insects (exuviae of Cicada) and wild fungi (Dictyophora indusiata) as drugs and foodstuffs, thereby increasing economical benefit of bamboo stands. Studies are underway to improve the management of such systems for better income.

(7) Garden type agroforestry.

Various models of garden agroforestry exist in the country according

to the ecological, social and economic conditions of different districts. For instance, in Hunan provinces (Longsan County) located in subtropical zone, a farmer has embedded 2200 timber trees and fruit trees both in front and at the back of the house. Among them there are 150 timber trees such as Chinese toon, Paulownia, Chinese fir, plane, bamboo; and 2050 economical trees such as phyllodendron, palm, orange, papaya, loquat, as well as many undergrowth such as pistache tree, Atractylodes macrocephala and beans. His annual economical income has reached 7000 yuan. In Anhui province's Dangsan County located in warm temperate zone, a farmer has planted 60 Paulownia trees around his house; these Paulownia trees are twelve years old, and their worth has exceeded ten thousand yuan. Under Paulownia trees, many grapevines are cultivated, and under the grapevine-rack multi-story rabbit-sheds established.

The above examples show a glorious future and great potential for developing agroforestry in China. The government of China devotes much attention to the development of agroforestry farming systems. Premier of the State Council, Zhao Zhi-yang, has said, "Stereoscopical agriculture should be carried on in China", and "In South China, crops-forest intercropping should be developed". Some provinces have held "developing stereoagriculture conferences", the participants of which are from agriculture, forestry, animal husbandry and soil and water conservation. With increasing support from the Government for improving farmers' incomes, agroforestry in China is bound to develop very rapidly in the near future.

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