The rubber/tea agroforestry system of South China: a short review

by

Walter E. Parham, Ph.D.
Honorary Professor
South China Agricultural University
Guangzhou, China

e-mail: parham305@aol.com

2000
Abstract

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Development of the rubber/tea agroforestry system by Chinese researchers, began in the 1960s on Hainan Island. The rubber/tea system was one of many agroforestry systems developed by the Chinese to help return productivity to South China’s degraded land and to provide new economic opportunities for the region’s people. The rubber/tea system involves planting bands of rubber trees between parallel bands of tea bushes in spatial arrangements that provide about 30 percent shade for the tea, the amount of shade needed to produce high quality tea. The tea in turn, helps to moderate the microclimate near the base of the rubber trees thus protecting the near-ground parts of the rubber trees and their roots from periodic damaging cold waves. The rubber/tea system helps assure the farmer has income from tea even when typhoons damage the rubber trees.

Numerous other benefits accrue to farmers and the natural environment by using the rubber/tea system versus planting monocultures of either one. Examples include: the rubber trees can be tapped for their latex one year earlier than normal and they produce larger quantities of product during their life time as do the tea bushes; runoff and soil erosion decrease; soil moisture, soil organic matter, and the number of soil microorganisms increase; root systems of both plants are enhanced in size and spread; and the income/unit area of the rubber/tea system is significantly higher than either monoculture.

Key words: degraded lands; intercropping; sustainable agriculture
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Introduction

Land degradation stemming from excessive vegetation loss is common throughout South China. Land clearing set in motion some physical, chemical, and biological processes that adversely affect all of the land's renewable resources and, thus, the quality of life and economic opportunities for the farmers. Excessive soil erosion and runoff, increased soil temperatures, loss of soil organic matter, and rapidly fluctuating temperatures of the microclimate arising from damage to the vegetative cover adversely affect agricultural development (Parham et al., 1993).

Chinese scientists have developed a variety of approaches to improve such degraded lands, including (a) solving soil erosion and soil nutrient loss problems, (b) developing a host of interesting intercropping schemes, and (c) developing agricultural production methods for risk reduction through diversity and incorporation of high-value commodities (Parham et al., 1993).

This paper summarizes the rubber (Hevea brasiliensis) and tea (Camellia sinensis var. assamica) agroforestry system, one developed by the Chinese. The technique, applied on damaged tropical soils on South China's hilly lands, has contributed significantly to slowing soil erosion, improving soil quality, and providing economic benefits to farmers.

Background

China grows rubber in Hainan, Yunnan, Guangdong, Guangxi, and Fujian Provinces under a monsoon climate. Its northerly growing limit is 24.7 degrees and its altitude limit is 1,500 m above sea level (Ma, 1989). Rubber trees do not grow satisfactorily in windy sites where the mean annual wind velocity is 3m/sec (Hao, 1986). In addition, rubber trees are sensitive to low temperatures. For example, a severe cold spell in 1976 killed about 25 percent of the rubber trees in Yunnan Province.
Planting times and planting conditions for rubber and tea generally are the same. Tea leaves are first collected when the plant reaches the age of three, its production peaks at 6-7 years, but production commonly can last for twenty-five years to as much as 50 years; rubber trees in monoculture plantations are tapped at age seven (Zheng et al., 1991). However, where rubber is intercropped with tea, rubber can be tapped safely at age six (Feng, 1989; Hao, 1986, and Zheng et al., 1991).

In addition to tea, Chinese farmers have intercropped rubber with food crops e.g. sweet potatoes (*Ipomoea batatas*), maize (*Zea mays*), cassava (*Manihot* sp.), peanuts (*Arachis hypogaea*); economic plants like coffee (*Coffea arabica*), pepper (*Piper nigrum*), sugar cane (*Saccharum officinarum*), lemon grass (*Cymbopogon citratus*), sisal hemp (*Agave sisalana*); fruits such as bananas (*Musa sapientum*) and pineapple (*Ananas comosus*); and traditional Chinese medicinal plants like *Alpinia oxyphylla*, *Amomum longiligulare*, and *Morinda officinalis* (Zheng et al., 1991). Such crops or combinations of them are grown under rubber trees to make use of available space at different heights to improve the effective use of the land resource (Zhu, 1994). Such systems can be highly effective in fixing carbon. For instance, a three story, artificial system of a windbreak, rubber stand, and legume cover crop in Danxian County, Hainan, PRC had a net primary productivity of 1853 gC/m²/yr, exceeding that of the seasonal tropical rain forest (Hao, 1986).

**Concept**

Research on rubber/tea agroforestry systems (referred to in the text as the rubber/tea system) started in Hainan in the early 1960s (Feng, 1986; Xu, 1993). Considerable attention was given to protecting the rubber trees from low temperatures because temperatures below 5°C can cause serious damage to rubber trees. Commonly, during such cold periods, the bark of the root collars of the rubber trees cracks, sometimes resulting in the death of the tree. Researchers believed that if they added numerous tea plants to the rubber plantations, the added plants might help protect the rubber trees from cold. In addition, the researchers felt that because the shallow rubber-tree roots are largely concentrated in the top 20 cm of the soil, the
tea plants would help lessen the soil heat loss and would also act as a wind break. The rootlets of the tea plants, on the other hand, tend to grow mostly between 20 to 50 cm below the soil surface. Therefore, the root systems of the rubber trees and the tea plants should be in minimal competition with one another for nutrients and water.

The Chinese researchers believed that if this intercropping scheme worked, the addition of the tea plants beneath the rubber trees would protect a large part of the rubber-tree root system from cold without the tea becoming a major competitor for nutrients and water. Consequently, various rubber/tea planting designs were tested to see how various rubber and tea arrangements might moderate the air temperature near the base of the rubber trees and protect the trees from excessive cold (Feng, 1986).

**Design**

The general method for establishing the rubber/tea system was derived partly from farming practices of Yunnan minority communities (Xu Z, pers. comm., 1990). The general planting procedure follows: plant and fertilize rubber-tree seedlings on prepared terraces; plant upland rice (*Oryza sativa*), maize, and peanuts and other leafy crops between the rubber trees; harvest the rice, maize, etc. at the end of year one; plant pineapples in spaces previously occupied by harvested crops; harvest peanuts in year two and pineapples in year two through year four; replant spaces previously occupied by pineapples with tea in year four; rubber trees at this point are tall enough to provide enough shade for tea plants; tap the rubber trees in year six; start tea harvesting three years after planting. The rubber/tea system can operate effectively for thirty years at which time the entire system is started again (Zhou S, pers. comm., 1990). The rubber/tea system is intended to keep the underlying soil covered with vegetation throughout the system’s life thereby minimizing soil erosion (Gong, 1989).

Experimental spacings in intercrops of rubber trees and tea bushes vary. Regardless of the spacings, the goal is to achieve about 30 percent shade for the tea to produce the best product (Feng, 1986). For example, one possible arrangement of 30 percent rubber trees with 70 percent tea bushes could be: two rows of rubber trees with the rows separated by 2.0 m,
and the trees in each row separated by 2.5 m; the lanes of rubber trees would be separated from one another by 18 m of tea bushes with the bushes separated by as little as 0.4 m or as much as 0.6 m (Zheng, 1991). With such an arrangement, the combined vegetative cover intercepts much of the energy of raindrops, thus reducing soil erosion (Gong, 1989). In other cases, rubber trees may be spaced as close as 1.5 m apart (Feng, 1986).

Physical and biological data

After planting densely spaced tea within stands of rubber trees, temperatures and wind velocities near the base of the rubber trees in the rubber/tea system showed moderation in winter with respect to those of monoculture rubber plantings. Further, the relative humidity within the rubber/tea systems overall was higher because of the complicated vegetation structure than in monoculture rubber plantings (Feng, 1989). The benefits of the rubber/tea system showed that the:

- daily average and maximum air temperature between 20 and 50 cm rose 0.3 - 0.4° C;
- night time rubber-tree trunk temperatures at 50 and 150 cm above the soil surface rose 0.6 - 2.1° C and 0.3 - 0.5° C respectively,
- relative humidity between 20 and 50 cm above the soil surface decreased 1 - 2% (Ma, 1989).

Overall, the rubber/tea system moderates fluctuations in its microclimate (Xu, 1993). The rubber/tea system keeps the system warmer in winter and cooler in summer than in a monoculture rubber planting. A shade range of 30-40 percent is beneficial to dry matter accumulation of the system (Feng, 1986; Huang et al., 1991) and also to the quality of tea (Huang et al., 1991). The rubber/tea system produces a higher soil organic matter content than a rubber monoculture because incoming sunlight is used more effectively (Feng, 1989).

With the increased vegetative cover of the rubber/tea system, runoff and soil erosion decreased and soil moisture increased (Feng, 1989). The increased vegetation and its close spacing in the rubber/tea system reduced the direct impact of the raindrops with the soil. In the rubber monoculture, only 12 percent of the raindrops were intercepted whereas in the
rubber/tea system 28.7 percent were intercepted (Xu, 1993). An eleven year comparison of runoff and soil erosion (Xu Z, 1993) shows the benefit of the rubber/tea system over monoculture rubber in slowing erosion and runoff (Table 1).

Because runoff slowed, the annual rate of water loss in the rubber/tea system was 42 percent less than that of a monoculture rubber planting. In addition, the rubber/tea system stored up to 150 t/H2O/ha more during the dry season than a comparable monoculture rubber planting and 322.5 tons more than a tea planting (Feng, 1986).

Subsequent analyses showed that the soil humus content of the rubber/tea system was 0.15 percent higher than that of a monoculture rubber planting, and 0.2 percent higher than that of a tea planting (Feng, 1986). The rubber/tea system also fostered a higher number of soil microorganisms, increased mineral nutrient availability, and improvement in the soil fertility (Feng, 1989).

Field research at the Xishuangbanna Tropical Botanic Garden in southern Yunnan Province provided data for the comparison of the bio-productivity of an eleven year old rubber/tea system with that of monoculture rubber plantings and monoculture tea plantings (Table 2) (Xie, 1989). Average net bio-productivity for the rubber/tea system showed a 42.4 percent improvement over monoculture rubber and 196.7 percent over monoculture tea.

Additional studies of the rubber/tea intercrop showed impressive data on the benefits of the rubber/tea system to root development (Table 3). Rubber-tree root development in the top 10 cm of the soil of the rubber/tea system surpassed similar measurements from monoculture rubber plantings (Song et al., 1989). In addition, the radius of the root spread in the rubber/tea system was at least six feet whereas the radius of the root spread of monoculture rubber was less than six feet. During the hot, dry season, the fresh weight/ha/month of absorptive roots in the top 10 cm of soil of the rubber/tea system was 370.5 kg whereas that of the monoculture rubber is 264 kg (Song et al., 1989). The above productivity is related in part to the system’s ability to absorb radiant energy. The rubber/tea system absorbs 71 Cal/m²/yr, the rubber
monoculture 44 Cal/m²/yr, and the tea monoculture 66 Cal/m²/yr (Xu, 1993).

The rubber/tea system provides additional benefits to the farmer. In monoculture rubber tree plantations, the trees are tapped normally at seven years of age. The farmer benefits from the rubber/tea system because in this system the rubber trees can be tapped safely one or perhaps two years earlier (Feng, 1989; Hao, 1986; and Zheng et al., 1991). Furthermore, the rubber trees of the rubber/tea system will produce latex five to six years longer than monoculture rubber thus extending the production period from 22 to 27 years (Feng, 1989; Zheng et al., 1991).

Because typhoons are common in South China, the establishment of wind breaks with associated rubber plantings is important whether the rubber trees are intercropped or not. An established wind break of 20-39 mu (1 mu=1/15 ha) can dampen wind speeds by 50 percent, or lessen the effect of a typhoon of 24.0m/sec by 55 to 68 percent (Hao, 1986). Wind breaks can lower the wind speed an estimated 30 percent at the top rubber tree canopy. In highly wind prone areas, dense wind breaks are established around each rubber planting of 10-15 mu (Hao, 1986). Dense upper story wind breaks with sparse lower story wind breaks are established around rubber plantings of 20-30 mu in size where winds are mild (Hao, 1986). Common wind-resistant trees used along China’s south coast are *Casuarina equisetifolia*, *Eucalyptus exterta*, and *Acacia auriculiformis* (Zhang et al., 1993) and some of these may be used as windbreaks for rubber plantings.

Changes in the direction of strong typhoon winds takes place with typhoon movement, thus, wind-break placement requires careful and thoughtful planning (Yoshino, 1989). The arrangement of rubber and tea in lanes helps to allow strong winds pass through the planting with minimal damage. Even in the event of wind damage to the rubber trees or in the event of a damaging cold period, the farmer has the backup economic benefit of having a valuable tea crop in place (Feng, 1986).

**Socioeconomic benefits**
Research findings on the economics of the rubber/tea system provide encouragement to local farmers in South China to use the rubber/tea system. By 1990, some 10,000 hectares had been put into the rubber/tea system in Yunnan Province (Xu, 1993). The rubber/tea system’s income/unit area was 58 to 131.5 percent higher than monoculture rubber, and 75.6 to 96 percent higher than monoculture tea (Feng, 1986; Feng, 1989; and Long, 1989); Xu (1993) showed rubber/tea income to be 82.7-85.6 percent greater than rubber monoculture. Further, the rubber/tea system increases the farmer’s land utilization ratio by 50 percent. Labor requirements are high for tending the rubber/tea system, thus affording large employment opportunities for the local populace (Xu, 1993; Zhan, 1989). Costly fertilizer additions to rubber-tree seedlings can also benefit other associated intercrops.

Discussion and conclusions

The rubber/tea system is one of many being investigated by Chinese researchers. Others include systems in which more than two major crops are involved. Intercropped systems with many native crops behave more like the original tropical forest that was replaced. For example, the Chinese report that where rubber, tea, legumes, medicinal plants, coffee, and pepper have been intercropped, soil erosion was reduced 94 to 98 percent, a figure not unlike that of the original tropical forest. Nevertheless, the rubber tree is an exotic species in China brought from Brazil and, therefore, any new agroforestry system in which it plays a part a major role will necessarily differ in some characteristics from the original tropical forest. Differences in the composition of the area’s original wildlife and bird assemblage should be expected particularly as the rubber/tea system is extended over large areas.

The Chinese data show that in the rubber/tea system, rubber production and tea production per unit area are greater than that derived from monoculture plantings of rubber or tea. An important contribution the Chinese researchers could make is to measure the Land Equivalent Ratio (LER) for various designs of the rubber/tea system. LER provides a measure of the yield advantage for the intercrop and the over yielding for each crop in the system (Gliessman, 1998). Such information helps to determine how much additional land would be
needed to achieve the same production of each of the crops if they had been planted as monocultures. This kind of information could help a farmer grasp the economic benefits of such systems and increase their appreciation for blending agricultural production thinking with ecological thinking especially where agricultural land is sparse.

An expert panel of the U.S. National Research Council (NRC, 1993) stated in a report on sustainable agriculture and the environment in the humid tropics that:

• "The vast body of indigenous knowledge on land use systems must be recorded and made available for use in national development planning" (NAS, 1993). It seems that the kinds of information summarized in this paper and the principles outlined by the Chinese researchers need increased attention by others whose goal is to improve tropical degraded lands. This summary paper is directed toward filling a part of this need. The NRC panel stated further that:

• "Throughout the humid tropics, degraded lands can be found that have the potential to be restored....but in many cases a scientific understanding and documentation of the process is incomplete (NAS, 1993). Data collected on the rubber-tea intercropped system in South China show that it has succeeded in bringing severely damaged lands back into productivity and in yielding significant economic benefits as well. Soil erosion has been slowed significantly using the system and soil moisture increased. Lastly, the NRC panel stated that:

• "The ability of a land use system to maintain high residual biomass in the form of wood, herbaceous material, or soil organic matter should be a primary requirement for restoring degraded of abandoned lands" (NAS, 1993). Here again, the Chinese data show that the above- and below-ground biomass and the soil organic matter produced in the rubber-tea system show large increases over monoculture plantings of either rubber or tea.
Acknowledgements:

The author wishes to thank Luo Shiming, President of the South China Agricultural University, and Director of the University's Agroecology Research Program, for reviewing this paper and making useful suggestions for its improvement. In addition, thanks go to Zu Xiaifu and Zhuo Shouqing, Director and Assistant Director respectively, of the Xishuangbanna Tropical Botanic Garden, Yunnan Province where in 1990, they introduced me to the workings of their various rubber/tea agroforestry system field experiments. Special thanks to Michael Benge, U.S. Agency for International Development, Senior Agroforestry Officer, for his thoughtful comments and careful review of this paper.

References


development of tropical and subtropical lands; Hainan, PRC, pp. 44-47.


Table captions

Table 1: Runoff and soil erosion rates under different land-use systems in Xishuangbanna, Yunnan, China; 1965 to 1986

Table 2: Measured improvements of the rubber/tea system over monoculture rubber and monoculture tea

Table 3: Percentage improvements of root systems in the rubber/tea system over monoculture rubber
### Table 1
Runoff and soil erosion rates under different land-use systems in Xishuangbanna, Yunnan, China; 1965 to 1986.

<table>
<thead>
<tr>
<th>land-use system</th>
<th>runoff</th>
<th>relative amounts</th>
<th>soil erosion</th>
<th>relative amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm/ha/yr</td>
<td></td>
<td>kg/ha/yr</td>
<td></td>
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<tr>
<td>tropical rain forest</td>
<td>99</td>
<td>(1)</td>
<td>63</td>
<td>(1)</td>
</tr>
<tr>
<td>rubber/tea system</td>
<td>206</td>
<td>(2)</td>
<td>2241</td>
<td>(33)</td>
</tr>
<tr>
<td>rubber monoculture</td>
<td>283</td>
<td>(3)</td>
<td>2694</td>
<td>(43)</td>
</tr>
<tr>
<td>shifting cultivation</td>
<td>3395</td>
<td>(35)</td>
<td>48,897</td>
<td>(778)</td>
</tr>
</tbody>
</table>

Xu Z (1993)
Table 2
Measured improvements of the rubber/tea system over monoculture rubber and monoculture tea

<table>
<thead>
<tr>
<th>Rubber/tea</th>
<th>Percent improvement over monoculture rubber</th>
<th>Percent improvement over monoculture tea</th>
</tr>
</thead>
<tbody>
<tr>
<td>standing biomass</td>
<td>147.19 t/ha</td>
<td>+38.0 %</td>
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<tr>
<td>average net bio-productivity</td>
<td>22.769 tC/ha/yr</td>
<td>+42.4 %</td>
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<tr>
<td>avg. economic productivity</td>
<td>2.639 t/ha/yr</td>
<td>+177.8 %</td>
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<tr>
<td>leaf area index</td>
<td>5.59</td>
<td>+107.8 %</td>
</tr>
<tr>
<td>solar energy utilization ratio</td>
<td>1.63%</td>
<td>+0.77 %</td>
</tr>
</tbody>
</table>

Xie J (1989)
Table 3
Percentage improvements of root systems in the rubber/tea system over monoculture rubber

<table>
<thead>
<tr>
<th>Rubber/tea</th>
<th>Improvement over monoculture rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>fresh weight of roots</td>
<td>198 %</td>
</tr>
<tr>
<td>dry weight of roots</td>
<td>165 %</td>
</tr>
<tr>
<td>total length of roots</td>
<td>312 %</td>
</tr>
<tr>
<td>total surface area of roots</td>
<td>322 %</td>
</tr>
</tbody>
</table>

Song et al. (1989)