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Article

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Coptis teeta (Ranunculaceae), is a nontimber forest product (NTFP) that only grows in northwest Yunnan and northeast India. Its tenuous rhizome, known as "Yunnan goldthread" in the traditional Chinese medicine system, has been used as an antibacterial and as an anti-inflammatory medicine for a long time. The increasing demand has resulted in commercial harvesting pressure on wild populations that were already dwindling as a result of deforestation, and wild populations are at risk of extinction. Fortunately, there exists at least 2000 hectares of a *C. teeta*–based agroforestry system initiated by the Lisu people in Nujiang, northwest Yunnan. This cultivation supplies us with a valuable study case for the balance between conservation and sustainable use. This case study investigated the traditional management system and history of *C. teeta* in Nujiang through ethnobotanical methods and field investigation. We also contrasted initial costs, economic returns, and labor demands for *C. teeta* cultivation with other major land uses in the region. Compared with swidden agriculture, the major land-use type in the region, *C. teeta* cultivation offers high economic returns and low labor and initial costs; moreover, *C. teeta* cultivation does not interfere with subsistence agricultural duties. This agroforestry system reflected that the cultivation of NTFPs is a conservation strategy for maintaining forest diversity, while providing a stable economic return to local forest communities, and indicates how local people manage biodiversity effectively.

INTRODUCTION

Nontimber forest products (NTFP) are one of the most important livelihood resources and an important supplement to agriculture for mountainous regions, including the eastern ranges of the Himalayas in northwest Yunnan (1–3). Mountain environments are characterized by rugged terrain and severe climate, with limited access to arable land and roads and to modern infrastructure. This explains a high level of dependency on natural resources (4). So far, these regions remain marginalized politically, culturally, and economically. For instance, in northwest Yunnan, the local economic system is largely characterized by subsistence agroforestry based upon extremely diverse land-use and biological resources (5). Collections of wild-plant resources provide not only a variety of basic needs but also an important source of income to local people (3).

Over the past two decades, environmental and cultural changes, demographic pressure and related effects, and economic development in remote mountain regions have accelerated, with a serious impact on natural resources. Commercial harvest of particular plant resources, especially medicinal plants for large-scale trade, may be unsustainable and lead to overexploitation and depletion of some species. This is likely to result in a loss of self-sufficiency and economic opportunity for local people. Overexploitation and unsustainable uses of biological resources can lead to resource-management problems and conflicts in cases where conservation areas become the focal points for the harvesting of selected species (3). This may result in a loss of diversity in conservation areas and enlarge the gap between the poor and the wealthy.

In the context of environmental deterioration worldwide, plant-resource management that may be conducive to solving problems related to conservation and development is now being given serious attention by the scientific community and some international organizations such as United Nations Educational, Scientific and Cultural Organization, World Wildlife Fund, International Centre for Integrated Mountain Development, and the Royal Botanic Gardens KEW. For instance, The People and Plants Initiative has, since 1992, developed a series of field projects aimed at finding appropriate conceptual frameworks and practices for the management of plant resources, building on indigenous and scientific knowledge. Community-based approaches have been used to address major conservation and related development issues. These case studies in Africa (6–11), Indonesia (12), Malaysia (13), Pakistan (4), and the Himalayan region (3) related to every aspect of conservation and sustainable uses of natural resources, describing processes, methods and approaches, attempts to shift from wild-plant harvest to cultivation, and economic analyses. "Conservation through cultivation," whereby cultivated sources of medicinal plants are produced to take pressure off wild stocks, is promoted by some of the above-mentioned studies but was rarely implemented on a large scale until recently. Agroforesty systems were mostly neglected as an important approach of cultivating medicinal plants on a commercial scale.

From ancient time, local people have developed knowledge about the utilization and management of diverse biological resources. They possess substantial information regarding soils, climates, vegetation types, stages of ecological succession, and land use, and, in many cases, have developed mechanisms or techniques to maintain biological diversity (14–16). For them, the mountain habitat provides a means of survival, not just an area from which resources can be exploited for short-term benefits (3). In northwest Yunnan, several agroforesty systems that are based upon interactions between traditional knowledge and natural conditions supply us with dramatic examples of how local people manage and maintain biological diversity for long-term benefits (17–19).

Northwest Yunnan is an area where two biodiversity hotspots, the Indo-Burma and South-Central China hotspots, meet (20). In particular, the Gaoligong Mountains are one of the major centers of plant diversity and a natural reservoir of medicinal plants (21). Here there are over 5000 higher plant species, including about 1000 species of medicinal plants (22). Although many species are being used by the pharmaceutical industry, few efforts have been made toward commercial cultivation of the vast majority of these medicinal plants. Instead, they are threatened by overexploitation and habitat destruction. In this region, particularly in the Nujiang Lisu Autonomous Prefecture (NLAP), the practice of shifting cultivation, swidden agriculture, and deforestation for timber extraction have been the most significant factors in habitat loss for a number of plants (2, 23).

Recently, medicinal-plant cultivation has been given serious attention, as is evidenced by recent moves toward modernization for Chinese medicine and also by the increased commercialization of pharmaceutical production by using traditional medicinal plants with known efficacy. Cultivation as an alternative to overexploitation of scarce traditional medicinal plants was suggested over 60 years ago (24, 25) and is regarded by foresters and conservationists as a strategy to maintain forest diversity while providing a stable economic return to local communities (6, 26). In the NLAP area, for example, 60% of people collect traditional medicines, including *C. teeta*, which was the fourth most popular medicinal-plant species among people interviewed around NLAP and was cultivated by over 70% of households (2). *C. teeta* has higher value and is much more in demand than other medicinal plants. To assure sustainable economic returns, as well as increase yields and use value, local Lisu farmers initiated its cultivation more than 100 years ago.

C. teeta is a typical and well-known NTFP. It is an understory species harvested from the moist temperate, evergreen, broad-leaved forests in northwest Yunnan, China, and northeast India (27–29) These forests, with a closed canopy and a stable microclimate, together with the specific structure and composition of the plant community, evidently help *C. teeta* to thrive in sites with fertile soils and a cooler, moist, highland climate (27). Its tenuous rhizome has a long use as a valuable traditional Chinese medicine known as "goldthread." Since the period of Sheng-Nong (3000 B.C.), goldthread has been used as an antibacterial and as an anti-inflammatory medicine. As a result of commercial harvesting for centuries and deforestation, few wild populations remain in this area (30). The species has entered into the Chinese Red Data Book (31). Fortunately, at least 2000 hectares of cultivated populations have been planted by the Lisu people in the forests of this region.

This paper documents the case of a *C. teeta*–based agroforestry system in the NLAP of northwest Yunnan. Specifically, our objectives were to *i*) summarize the traditional knowledge of cultivation and harvest for *C. teeta*; *ii*) compare the initial costs, economic returns, and labor demands of *C. teeta* cultivation with other major uses of forested land in the region; and *iii*) assess the agronomic potential of *C. teeta* and its capacity to foster forest conservation in northwest Yunnan.

MATERIALS AND METHODS

Description of Site and People

This study was carried out in Zhumilin, a Lisu community of about 450 people in Fugong County in central NLAP. Fugong has had reserve status since 1985 but was reclassified as part of the Gaoligongshan National Nature Reserve (GNNR) in 1999. In spite of this, over the past four decades, deforestation for swidden cultivation and timber extraction destroyed 58% of Fugong's forested areas (32, 33). Today, although any disafforesting activity is prohibited within the buffer zone by the related laws, as with other National Reserves in China, the buffer zone forests of GNNR continue to be cut down for swidden cultivation and very little primary forests remain. This community comprises an area of about 621 hectares and consists of 285 hectares of farming land. Its seven villages are from 1900 to 2500 m above sea level. The farming lands are quite steep, with most of them at a slope of over 20 degrees; the steepest slope reaches 60 degrees. The local farmers still retain their traditions in religion, culture, production practices, and lifestyles. The local people were polytheistic in the past; but, since the introduction of the Christianity in 1920s, most people have combined both Christianity and polytheism. In particular, they worship forests, trees, animals, lands, mountains, and rivers, so a few primary forests remain here. Their production activities mainly include swidden agriculture, *C. teeta* cultivation, timber and nontimber forest products harvest, and animal husbandry (e.g., cattle, goat, and chicken). Among these activities, swidden and *C. teeta* cultivation are the most important and oldest ones.

Zhumilin is located on the east slope of Gaoligong Mountains, within the reserve's buffer zone, and was the first Lisu community to cultivate *C. teeta*. There are still about 100 hectares where *C. teeta* is planted. *C. teeta*–based agroforestry system here is not only the most typical and representative one of the NLAP but has also recently been selected by governmental agencies as the site of a pilot project for *C. teeta* cultivation on a large scale. The vegetation is classified as subtropical wet forest (32) although the landscape today is a mosaic of primary and secondary forests and cultivated land. The average annual temperature is 12.1° C, average annual precipitation is 2355 mm (27), and altitude ranges are 1900–3100 m. There is a heavy rainy season, which extends from May to November, and a dry season from December to April.

Investigation Methods

As a part of the project of conservation biology for *C. teeta,* this study was implemented from 2002 to 2004, with the main aim of applying ethnobotanical approaches to conservation-biology research. The research consisted of two components: first, collection of information regarding cultivation history, trade quantities, and land use from local government agencies; second, field visits to the main areas where harvesting takes place or where cultivation is implemented in NLAP. During two visits in May 2003 and October 2004, respectively, we held discussions with harvesters, cultivators, foresters, and medicinal-plant vendor/wholesalers. Participatory rural appraisal (PRA) was the most important tool to gather information on agroforestry. The importance value assessment and scoring of cultivated plants were also from PRA methods (34, 35).

Semistructured interviews were held with selected knowledgeable elders (key informants). Twenty-four key informants (21 men and 3 women between the ages of 45 and 69 years) were chosen with the assistance of the local forestry department authorities and community leaders. Each informant was interviewed three times to verify the reliability of the data. Repeat visits yielded additional information that was not mentioned in initial interviews. Interview responses were recorded in a notebook. At times, a tape recorder was used. Photographs were also taken when necessary. Most of the interviews and discussions were organized in Mandarin Chinese; a few interviews were carried out in the Lisu language with the help from a local researcher, Mr. Zhou Yuanchuan, who is familiar with the local biophysical environment and languages. Each interview lasted from two to four hours during a single day. Information related to land preparation, transplanting, management, harvesting practice, and economic evaluation was also collected. Preference ranking (36) was used to rank some crops according to their economic importance. This is a simple analytical tool that involves asking people to think of five to seven items and arrange them according to a given criterion. In our study, the most important item was assigned a value of ten, whereas the least important was

Table 1. Characteristics of the farming lands of the Lisu people in *Zhumilin* community.

Land category	Tongbami	Sanjiemi	Kemi (swidden)	Shinemi (woodland)
Altitude (m)	1600–1800	1800–2100	1900–2800	2200–3000
Slope (degree)	20–25	25–30	25–40	20–35
Land preparation	Plowing with cattle	Digging	Digging or Burning	Digging
Area (ha)	8	17	160	100
Crops	Corn, vegetables, potato, soybean	Corn, potato, pea, soybean	Corn, pumpkin, hemp, buckwheat, barley	*C. teeta*
Farming duration (y)	Permanent	Permanent	1 (−10)	Permanent
Fallow duration (y)	None	None	3 (−15)	None
Tenure	Common property	Common property	Common property	Private property
Fallow management	None	None	Lacquer/alder (partly)	None

assigned a value of one. These numbers were summed for all respondents, giving an overall ranking for each crop.

RESULTS

Farming Land Category and Swidden Cultivation of the Lisu

There are four types of farming lands in Zhumilin (Table 1), namely dry fields prepared by animal labor (*tongbami* in Lisu language), dry land by human labor (*sanjiemi*), swidden land (*kemi*), and woodland (*shinemi*). *Tongbami* and *sanjiemi* occupy an area of less than 30 hectares. *Kemi* is on the steepest slopes and is the largest type of farming land in the community, on slopes of 25–40 degrees (a few are over 50 degrees) and an area of more than 160 hectares. *Shinemi* is only used to cultivate *C. teeta* on slopes of 20–35 degrees mostly under the canopy of the secondary forest and is prepared only by manual labor. Its area is slightly less than that of swidden among these farming lands. According to our field surveys, about 80% of the Lisu's food and 30% of their cash income come from swidden cultivation; over 50% of their cash income comes from *C. teeta* cultivation. The Lisu people mainly grow food crops in their swidden fields. A few other species, especially lacquer (*Toxicodendron vernicifiuum*) and black alder (*Alnus nepalensis*) are also cultivated in the swidden fields. The forest can become *shinemi* when *C. teeta* is cultivated on them. After small shrubs and grasses are cleared, the land will be prepared by digging slightly using manual labor.

Cultivation and Management of *C. teeta*

Ramets collecting. Late May or early June is the beginning of the rainy season and when the ramets are the most flourishing and the strongest in the year. The Lisu men carefully choose stouter and stronger plants that have grown as high as about 25 cm, then pull up their exuberant ramets, sometimes associated with livelong plants carefully with wooden sticks or hands. The plants chosen from the same population are as far apart as possible.

Transplanting ramets. Within 1–2 days, or preferably on the same day that the ramets are collected, the ramets associated with their mother plants will be transplanted to the new *shinemi*. Because this land is located in the evergreen broad-leaved forest, with an average altitude of over 2200 m above sea level, the soil, with abundant humus, is very fertile and moist. The ramets are smoothly laid into a small depression, about 15 × 6 cm and about 2–3 cm deep, and then are covered with the mixture of soil and humus. After transplanting, the field will be irrigated slightly. About 1500 ramets can be planted on one hectare of land.

Managing C. teeta. For one to two years, the Lisu farmers tend the young *C. teeta* by weeding, fertilizing with ash from burned shrubs and grasses, and pouring water in dry season. Unlike other farming systems, it is unnecessary to till the soil. After three years, a few branches of trees in the *shinemi* need to be pruned so that more light can reach the ground under the tree canopy, and the Lisu people believe that through this method they can receive greater yields of the rhizomes. A few *C. teeta* plants may be affected by fungus, and they must be cleared away from this *shinemi*. Our field survey indicated that the Lisu people used very little pesticide and chemical fertilizer in this *C. teeta*–based agroforestry system.

Harvesting rhizomes. Although the life cycle of a single plant is about 10 years, *C. teeta* is characterized by vegetative reproduction. The *shinemi* can yield rhizomes almost indefinitely when they are regularly harvested and the forests are not destroyed. After the ramets are transplanted, four to seven years may elapse before the first harvest, which is when the rhizome diameter reaches about 1.5 cm. Based on the investigation from the selected informants, in late November, when the rainy season ends and the dry season begins, the oldest leaves of *C. teeta* become yellow and withered, and the vegetative growth of the plants stop. At this time, the Lisu men check the size of the rhizome in the loose soil with their hands and then carefully sever the suitable rhizome from mother plants with a small knife instead of hurting other unsuitable rhizomes or ramets. By this wise way, the Lisu farmers can harvest rhizomes year after year. In our survey, in fact, the rhizomes were harvested by the local people only during special days of any month in one year but generally after the plant had completed the sexual cycle.

Rhizome trading. Before 1950, farmers mainly sold rhizomes to traders near their home, then the traders sold to wholesalers in bigger towns. The wholesalers exported these products to southeast Asia through TengChong, an important business center neighboring Burma in the northwest, and transported them to inland China by the Yunnan-Burma road. The sales volume per annum was 5–10 tons. From 1950 to 1985, during the state monopoly for the purchasing and marketing of all medicinal plants, the average sales volume per annum was 10–20 tons. Since 1985, with the policy of encouraging diversified economic activities, the farmers perceived this as a crucial incentive to cultivate and harvest *C. teeta*. Subsequently, business organizations at all levels (including private traders) have been engaged in the purchasing and marketing of rhizomes, moreover, many of the farmers now have direct connections with big wholesalers or medicinal materials companies in the big cities, such as Dali and Baoshan and even Kunming.

Benefits from *C. teeta* Agroforestry System: Costs, Economic, and Environmental Returns

Although corn is the Lisu's staple food crop, as a result of lower level of productivity and difficult natural environment, the output of corn from their swidden is not sufficient to use as human food and cattle feed. The short parts should be

Table 2. Preference ranking values of cultivated plants in Lisu's farming systems in *Zhumilin*, Nujiang Lisu Autonomous Prefecture, northwest Yunnan, China, according to the participatory rural appraisal procedure.

Crop	Scoring by key informants (coded A to L)												Total score	Ranking
	A	B	C	D	E	F	G	H	I	J	K	L		
Alder tree	1	2	2	1	2	1	1	3	2	1	2	1	19	11
Barley (*Hordeum vulgare*)	2	3	3	2	1	4	3	2	2	2	2	3	29	8
Buckwheat (*Fagopyrum tataricum*)	3	3	4	4	5	4	4	3	3	2	4	3	42	5
Cannabis sativa	2	2	3	2	3	3	2	1	2	3	2	3	28	9
Coptis teeta	10	10	9	10	9	8	7	8	9	10	9	8	107	1
Corn	8	7	7	8	6	7	8	7	8	7	7	7	87	3
Lacquer tree (*Taxicodendron verniciflum*)	8	7	8	7	7	8	9	7	7	8	8	8	92	2
Potato	2	3	3	4	4	3	4	3	1	2	3	3	35	6
Pulses	5	6	6	4	5	5	6	6	5	4	4	5	61	4
Pumpkin	2	2	1	2	3	2	1	2	3	2	2	3	25	10
Tung tree (*Aleurites fordii*)	2	2	3	3	4	2	3	2	3	2	3	2	31	7

purchased from the market with cash. *C. teeta* is almost the only cash crop in Lisu society and plays an important role in the Lisu's economy according to our results when using the PRA method. Some 30 years ago, the rhizome of *C. teeta* was the only source of cash income. The Lisu people relied on it to buy or to barter for food, clothes, salt, iron tools, and other items for daily uses. Once the rhizome of *C. teeta* was used as an universal equivalent in NLAP. Today, it is still the Lisu's main source of cash income.

The PRA methods were used to quantify the local people's perspectives on their crops. Preference ranking values (based on their economic importance) obtained from the overall ranking for the planting crops (see Table 2) by 12 informants showed that *C. teeta* is the most important, followed by lacquer, corn, pulses, buckwheat, potato, and other cultivated plants in this community.

The major uses of forested land in NLAP are listed in Table 3. We included lacquer tree cultivation in this comparison. In the past, the Lisu people only grew lacquer trees on their permanent farming land instead of in their swidden fields, and only collected leafy shoots as a vegetable and gathered seeds for vegetable oil extraction, but they did not tap resin. The resin is the most important source of cash income in the Lemo (a branch of the Bai minority nationality) community. Because the Lemo's indigenous knowledge of lacquer agroforestry system was disseminated to neighboring Lisu's communities recently, the lacquer trees have become an important source of cash income from swidden cultivation and a major use of forested land in many parts of NLAP, including *zhumilin*. The costs of establishing one hectare of forest with C. *teeta* or with lacquer were similar but represented about half the cost needed to establish *makami* for producing food crops on the same amount of land. In *zhumilin*, the high costs and low economic returns of food crop cultivation in swiddens resulted in most members planting some species of trees with economic value, particularly lacquer trees, or letting their land regenerate naturally. The natural renewal of swidden for conversion to secondary forest not only requires zero investment of time or money at present, but farmers also acquire a sum of money for compensation from the government.

The number of labor-days per year required for *C. teeta* cultivation was less than a third as much as that needed for food crop cultivation and half that needed for lacquer cultivation. However, the estimated net income value per hectare from *C. teeta* cultivation were almost 15 times as high as that obtained from food crop cultivation and nearly twice as much as that from lacquer cultivation.

This *C. teeta* agroforestry ecosystem is similar to natural forests in structure and function. The vertical structure of the vegetation consists of 3–4 layers, i.e., the first layer is 20–30 m high and the cover is more than 80%. The dominant plants are *Cyclobalanopsis* spp., *Manglietia insignis*, *Machilus tenuipilis*, *Lithocarpus hancei,* and *Litsea subcoriacea*. Young trees of these arbors, *Rhus chinensis* Mill and *Castanopsis* spp., occupy the second layer, at a height of 10–20 m, with the cover degree of 3–50%. The third layer is 3–10 m with the cover of 60%–70%. The dominant plants are *Rhododendron* spp., *Fargesia contracta*, *Damnacanthus indicus* and *Viburnum cylindricum*. The forth layer is less than three meters high with the cover of over 80%, and *C. teeta* is the main species.

DISCUSSION

The sustainable harvest of NTFPs is a conservation strategy for maintaining forest diversity while providing a stable economic return to local forest communities (26). Evidence of overexploitation by commercial collectors has been demonstrated, which contradicts the assumption made by Olsen (37) that collection by commercial collectors is sustainable and that they regulate their practices, access to resources, and regeneration of plant populations. There is thus a need for balancing local knowledge with scientific knowledge to ensure long-term planning and conservation of plant resources. The cultivation of shade-tolerant NTFP under the forest canopy can increase NTFP yields and decrease pressure on wild populations (36, 38). The cultivation of alternative sources of the supply of popular, high conservation priority species outside of core conservation areas is, therefore, essential. However, commercial cultivation of such species is not a simple solution and, at present, is unlikely to be profitable, because of the slow growth rates (6, 8). *C. teeta*, as the most vulnerable species that is popular, slow growing or slow to reproduce, species with specific habitat requirements and a limited distribution, was recognized as difficult to cultivated (6). But through traditional cultivating practice as this study showed, *C. teeta*–based agroforestry system not only ensures sustainable use of this medicinal plant but also promotes conservation of the forest ecosystem.

Economic Returns and Labor Demands

Northwest Yunnan, where the Lisu people live, is a poor region according to the national criteria. The Gross Domestic Product (GDP) was only 732 Chinese Yuan (about 90 USD [1 USD = 8.24 Chinese Yuan, December 2004]) per capita in 1999 (39). Their cash income was as low as 224 Chinese Yuan (about 30 USD) per capita (or 120 USD per household), of which most was from selling *C. teeta* rhizomes and lacquer resin. As a result of *C. teeta* cultivation on a large scale, *zhumilin* is one of the richest communities in NLAP. For example, an average household maintains one hectare of the *C. teeta* field (less

Table 3. Estimated costs and economic returns of forested land per hectare in Nujiang Lisu Autonomous Prefecture.

Land use	Cost of establishment,[1] Chinese Yuan, ¥ (USD)	No. y until production	Net annual income once production begins (above personal use), ¥ (USD)	Annual labor requirement during years of production (Labor days y^{-1})
Food crops cultivation	800 (97)[2]	0	200 (24)	142
Lacquer cultivation[3]	450 (55)	6–8	1650 (200)	89
C. teeta cultivation	375 (46)	4–7	3000 (364)	42

[1]Including cost of labor involved in establishment.
[2]2004, 1 USD = 8.24 Chinese Yuan.
[3]Data from Long et al. (2003).

one-third hectare in other communities). Thirty kilograms of rhizomes can be produced in a yield year from one hectare of the *C. teeta* agroforestry system. The average selling price in local markets was 100 Yuan kg^{-1} recently, thus 3000 Yuan (about 364 USD) cash can be received in a year per household by selling the rhizomes. From this point, it is not surprising that the Lisu people treat *C. teeta* as their number one crop.

Our results indicate that *C. teeta* cultivation offers farmers annual economic returns that are almost 15 times greater than those food crops obtained from swidden and that costs of establishment and annual labor demands are significantly lower as well. These economic incentives are of great significance in the Lisu's communities in NLAP, where about 90% of farmers practice swidden agriculture, but the great majority do not produce enough food to feed themselves.

Our results indicate that the timing of labor requirements for *C. teeta* cultivation poses little conflict with most farmers' labor schedules. For instance, our data suggest that the optimal time for harvesting *C. teeta* rhizomes is the late wet season or the early dry season (November–December), when leaves are the largest and stop growing. Likewise, the optimal time for transplanting ramets appears to be the early wet season (May–June), when ramets production is the highest and when mortality is probably the lowest. Although we did not measure seasonal variation in mortality, it appeared to be the greatest during seasonal extremes, i.e., the driest periods of the dry season and the wettest periods of the wet season. The timing of these activities, which represents about 90% of *C. teeta* labor requirements, does not conflict with the labor requirements for swidden agriculture or lacquer cultivation. Ninety-three percent of the labor demands for swidden agriculture (preparation of land, planting, weeding, fertilization) occur from January to June, and the harvest takes place in September. Similarly, lacquer harvest runs from July to October. This is important, because in the lacquer-growing regions of northwest Yunnan, lacquer harvest represents about 30% of a farmer's annual labor requirements (19).

It must be emphasized that, although our results indicate that harvest may be optimal at certain times of the year, *C. teeta* rhizome is obtained from vegetative structures and can, therefore, be harvested and converted to cash at any moment. Thus, like cattle or poultry, *C. teeta* plantations can act as a type of bank for farmers. Having an emergency source of cash accessible is essential for farmers who generally have no other forms of savings.

The fact that almost all the labor demand associated with *C. teeta* cultivation is concentrated in the harvest also holds significance for the agronomic and conservation potential of this species. Over the past four years, increasingly degraded soils and the lack of employment opportunities have driven growing numbers of NLAP farmers to work as seasonal laborers in factories in bigger cities. Because *C. teeta* cultivation requires little or no maintenance during most of the year, farmers have been able to maintain their cultivated forest plots even while they are gone. The only other option available for migrant farmers is to lease out their forested lands for natural regeneration.

Ecological and Economic Costs

The cost of severing ramets from their mothers for transplanting was evidenced by the fact that during first the one and a half years of growth, individuals of wild populations grew faster than their cultivated counterparts. In many perennial herbs, newly produced daughter ramets are strong sinks for assimilates (40). Severing has, therefore, been shown to decrease rates of growth and survival of ramets in this species, as well as in others (40). Recent data from *C. teeta* cultivators also suggest that transplanting the larger and attached mother ramets results in higher growth rates and lower mortality rates.

These ecological costs of cultivation and the fact that the plant takes at least four years to harvest rhizome with commercial length may act as disincentives to farmers. Cultivation also implies economic costs, because it requires labor for the transplanting of ramets to plantation sites. In some regions, therefore, institutions promoting the cultivation of *C. teeta* have offered to help farmers cover the labor costs associated with plantation establishment.

Cultivation, however, cuts labor demands for harvesting (compared with wild populations), because travel time is greatly reduced. Moreover, the observations on the mode of rhizome harvesting by the local farmers suggest that their methods and cultural practices were the best ways by which the species could be used on a sustainable basis. This mode of harvest and ramets collection for transplanting can ensure a lower density. Once ramets acclimate to their new environment, they grew faster under the lower-density conditions. High density has a negative effect on growth and survival in many clonal species in general (41). Based on our recent studies on *C. teeta* (42), cultivation of *C. teeta* has developed and strengthened its vegetative production, and ramets produced rapidly contribute to a large increase in population size. As a result of this vegetative propagation, the Lisu farmers can use this important resource continually.

Can Cultivation Foster Forest Conservation?

The high economic returns obtained by cultivating *C. teeta* compared with other land uses, combined with the socioeconomic implications of its cultivation, suggest that farmers may have important incentives to cultivate *C. teeta*. But can *C. teeta* cultivation actually foster forest conservation?

Cultivation can help to maintain forest canopy, because *C. teeta* requires shade to grow (27). Pruning branches, to increase light, to 60% canopy cover of the third year results in low rates of leaf production but increasing allocation of resource to growth of rhizome.

Loss of habitat and understory eradication (e.g., swidden cultivation) associated with overexploitation resulted in the depletion of *C. teeta* populations. Thus cultivation of *C. teeta* may be considered, to a certain extent, as restoration. Comparative studies of biodiversity in forests with and without *C. teeta* plantations and in diverse agroforestry systems with *C. teeta* would provide more insight on the potential of the cultivation of this species to foster biodiversity.

The cultivation practice of *C. teeta* in *zhumilin* forests, however, has already demonstrated that adding economic value to forests can foster their conservation. A large part of the community's forests has been planted with some *C. teeta,* and in, an effort to safeguard their crops, community members had intentionally not grazed their cattle around the forests. Similarly, the community passed a local law prohibiting the destruction of its forest because of its potential as *C. teeta* habitat.

In Gaoligong Mountains and other reserves, the conservation potential of *C. teeta* can extend beyond the buffer zone forests. For example, increasing the economic returns of local farmers might decrease financial pressure that forces them to go into the core area of the reserves and illegally harvest

Potential Limitations to Cultivation

As for any species, the potential for *C. teeta* to provide economic and ecological benefits faces limitations. For instance, fungal attacks may pose one problem for successful cultivation. Although a few pests or fungal diseases have been observed in some forest populations, outbreaks of fungi have destroyed a few populations growing in association with fruit trees in other parts of the prefecture and in the populations transplanted to Kunming, the capital of Yunnan Province. This points to the importance of cultivating genetically diverse plants. *C. teeta* may propagate by seeds, even though, as is the case for most clonal species (43), seed-grown plants grow slower than plants that are propagated vegetatively. Although our results indicate that harvesting rhizomes may have little impact on plant growth, this form of propagation may have a negative impact on genetic diversity, because the rhizome may be where this species stores its energy for flowering. Based on the experiences of farmers in regions of fungus outbreak, and taking into consideration the economic necessities of most farmers, we recommend that at least 10% of all cultivated plants should not be harvested so that they can reproduce sexually. However, cultivating seedlings may greatly increase the output, and this has been proven in the case of *Coptis chinensis* cultivation in Chongqing, southwest China (30).

The dependence of *C. teeta* on market forces may also pose potential limitations. Although goldthread is an important traditional Chinese medicine and there is a big demand, *C. teeta* is only one of the "goldthread species." Because of lower output, it cannot compete with other species with higher output (e.g., *C. chinensis*). Therefore, whereas *C. teeta* may provide important economic benefits to farmers in the short term, there is no long-term guarantee. Careful planning on the part of the agencies promoting this crop will be necessary to avoid overproduction. *C. teeta* cultivation should be promoted as a complement but not a substitute to subsistence farming.

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