Chapter 11

Using Agrobiodiversity for Developing Marginal Mountain Agroecosystems: The Experiences of a Pilot Project in the Tiahang Mountains, China

Yang Yonghui, Geng Qingguo,
Cao Tiesen, and Zhang Wanjun

The Taihang Mountains

The Taihang mountains in China cover an area of 100,000 sq. km. from 114° 15' E, and 37° 52' N onwards. The pilot area is in a part of the Taihang mountains 50 km southwest of Shijiazhuang, the capital city of Hebei Province, and 310 km southwest of Beijing. The experimental site was a seriously degraded one.

The climate in this region is characterised by an abundance of sunshine, low relative humidity, and an average evaporation of 1,589 mm per year. Average annual precipitation is 579.6 mm, 77 per cent of the rainfall occurring between June and September. The temperature is extremely variable. The annual average temperature is 13°C, varying between -11 and 39.3°C.

Seventy per cent of the mountainous areas are slopes where the soil is very shallow and stony. The soil in the valleys is relatively good with a better moisture holding capacity. The population density in the Taihang mountains is extremely high at 245/ km. Farmers are very poor and the average per capita income is about US$ 43.

Studies were carried out at the Experimental Station of Ecology in the Taihang mountains to test conservation and whether rehabilitation of agrobiodiversity can play a key role in improving the environmental conditions and providing socioeconomic benefits to economically disadvantaged farmers.

Limitations to Environmental Rehabilitation

During the 1950s, a lot of investment was made to improve the environment in the Taihang mountains through an afforestation programme. Even so, the forest cover in this region is still less then 20 per cent. The reason for this is that the government paid too much attention to the improvement of the environment through afforestation with timber trees, and ignored the farming economy of the inhabitants. Trees planted during the 1950s and 1960s are still only six to eight metres tall with a diameter at waist height of less than 20 cm.

Conventional scientific thinking in China and elsewhere considers afforestation as a means of environmental rehabilitation. Forests can also be developed on marginal lands where the environmental conditions limit the development of crop production. Few lessons have been learned from the way peasants live in these areas. The local people were not allowed to use trees planted for environmental purposes in this area. For 30 years, the peasants obtained little economic benefit from these activities and they became nervous about afforestation. We tried to combine these two different aspects; environmental rehabilitation through afforestation and providing economic benefits to local farmers; by planting *economic* commercial fruit trees that have a relatively quick turnover.

Experiment and Results

Introduction of Economic Trees

Our surveys revealed that *economic trees* (in China fruit trees are understood to be economic trees) in the Taihang mountains were not very productive and the quality of their fruit was not good. Some varieties needed to be replaced for the market. The Experimental Station introduced a total of 347 species and varieties, including 45 varieties of pomegranate, six varieties of persimmon, 14 varieties of apple, 20 varieties of grape, eight varieties of cherry, 28 varieties of walnut, 28 kinds of forage herbs, and medicinal herbs. One hundred Chinese *mu* (6.7 ha) of land was used to test the adaptability of these species and varieties. During the ten-year experiment, more than 50 species and varieties were identified suitable to the harsh environment of the Taihang mountains.

Improvement of Native Walnuts

The walnut is a traditional tree species in the Taihang mountains. It is well adapted to drought and the low fertility of soil in the area. The productivity of local walnuts is very low (1.35 kg/tree per annum), however, and the quality of the fruit is considered poor as the shell is very difficult to break. There is little demand for local walnuts in the market. Fine walnut cultivars were grafted on to 354 old and low yielding trees in the early spring of 1988 to improve the productivity of walnuts. Since the old trees contained a lot of stored energy, new branches from the grafted buds grew very fast (Table 11.1). At the end of the second year, the tree crowns had reached 4.7 to 5.9m and 87 per cent of the trees gave some

Table 11.1: Yield of Old Walnut Trees in 1989, Two Years after Grafting				
Walnut variety	No of nuts per tree	Weight of nuts per tree (g)	Weight of dry kernels per tree (g)	Length of branches from each newly grafted bud
Liaohe 1	216	2383	1281	138.6
Liao 50609	202	2343	1337	-
Zhonglin 1	163	2039	1076	123.4
Zhonglin 5	187	1877	1133	-
Bofeng	190	2179	1146	156.0
Liao 50706	174	1829	926	151.0
Lubo	181	1852	1100	109.9

fruit. The average yield of seven well-adapted cultivars was 1.83 to 2.38 kg/tree. The average yield of these seven steadily increased to 3 kg/tree, that is 7.1 times the average yield of these trees in 1987.

Introduction of Pomegranate Cultivars

The pomegranate is a widely distributed species in the Taihang mountains and usually grows on the driest south-facing slopes. The fruit is usually very sour and the market for such quality is not good. The fruit fetches only half the price of sweet pomegranates. Most fruits are used for canning. However, the pomegranate is one of the few fruits that can be farmed on the very dry southern slopes of the mountains and it has good storage qualities. Therefore promoting pomegranates in a programme to rehabilitate degraded land could help to improve farmers' living conditions as well as to conserve native species.

Since 1987, more than 50 cultivars of pomegranate have been introduced at the Experimental Station. Several integrated methods were used to establish pomegranate plantations. These were:

- improvement of the micro-site environment,
- conservation of soil moisture, and
- introduction of new varieties.

Table 11.2 shows the degree (%) of adaptability under different mulching treatments compared to other local species.

Table 11.2: Establishment of Pomegranates and Other Fruit Trees and Degree of Adaptability under Different Mulching Treatments (comparison with other species)					
Tree species	plastic film	grass	stone	turf	control
Pomegranate	98.0	84.7	86.2	73.6	62.6
Local apricot (*Prunus sibirica*)	95.8	86.4	85.3	78.2	72.4
Local peach (*Prunus davidiana*)	96.9	85.6	85.8	76.0	67.5

Pomegranates are well placed on the south facing slopes of the mountains to avoid chilling. Ten cultivars of pomegranate withstood the drought and shallow soil conditions (Table 11.3). Seven cultivars produced a better yield than the others. The highest yielding cultivar was Erban which produced 11.7 kg fruit per tree compared to 2.0 kg/tree for the local land races.

Table 11.3 : Yield Performance of Pomegranates

Cultivars	Yield (kg/tree)	Mean fruit weight (kg)	Weight of biggest fruit (kg)	Weight of 100 grains (g)	Taste
Baden	4.75	140-170	300	52.0	Sweet
Erban	11.70	150-350	500	39.0	Sweet
Sanbt	2.75	120-280	380	27.7	Sweet
Yusz	6.50	100-330	390	48.0	Sweet
Daht	6.25	130-270	300	41.5	Sweet
Fenpi	2.70	100-250	250	39.2	Sweet
Chongbh		30-50	48	12.7	Sour
Qianch	0.60	190-350	420		Sour
Hongpt	0.35	70-100	140	23.0	Sweet
Tianhd	3.10	100-200	250	25.7	Sweet
Luyd	1 40	100-250	330	24.3	Sweet
Dazz	1.00	100-280	280	22.2	Sour
Mapz	0.50	100-150	200	22.1	Sweet
Maith	2.00	100-200	250	28.0	Sweet

Sweet Persimmon Tree

The persimmon is another indigenous fruit tree that grows wild in the Taihang mountains. The trees mostly grow wild in the valley areas where the soil is deep. *Persimmonis* is a drought-resistant plant. Its fruit is eaten fully ripe and therefore fruit storage is difficult. Because of this the prices fall as production increases. Six varieties of persimmon were introduced and evaluated. Of these, Dansiwan, Fuyou, Colong, and Songben contain no tannic acid so the fruit becomes sweeter before ripening. This helps solve the problem of storage and transportation of ripened fruit. Fruit from these cultivars can be sold 20 days earlier or stored for a longer time.

Medicinal Plants

The Taihang mountains are famous for their richness in medicinal plant species. The demand for Chinese medicine has been increasing as a result of improvement in the economic status of people. Therefore more medicinal products are needed in the market. As Chinese medicines are becoming expensive, there is a demand for more raw materials, and this is leading to overexploitation of nature. Thus many species of medicinal plants in hilly areas are endangered. The purpose of the study in this case was to collect endangered species and try to domesticate them on the farmlands of the Taihang mountains so as to increase incomes. Box 11.1 gives examples of high-value medicinal plants found in this area.

About 60 species of medicinal plants were planted in the experimental region. Of these, 18 species, including *Astragalus membranaceus, Perilla frutescens, Schizonepeta tenuifolia,* and *Cassia tara,* have been shown to be drought resistant species which can grow well on the dry slopes of the mountains. Fifteen species, including *Tagetes erecta, Achyranthes bidentata, Angelica dahurica,* and *Agastache yugosa* can be cultivated easily in shady environments. Two species, *Pinellia pedatisecta,* and *Corydablis bungeana,* can only be planted in shady conditions with a good soil moisture content.

Wild medicinal plants usually love a shady environment and thus cultivation can be integrated into agroforestry or mixed with other crops. There are several possible intercropping systems, for example, intercropping of fruit trees, such as pomegranate, walnut, apple, and apricot, with medicinal plants and shrubs such as *Forsythia suspensa, Eucommid vimodies, Macrocarpium papyrifera, Belamnenda chinensis, Anemarrhena aspehodeloidees, Arctium lappa, Angelica dahurica, Salvia miltiorrhiza, Ophiopogon japonicus,* and *Adenophora elata.*

Forage Herbs

A total of 29 species of forage herbs was introduced to improve soil fertility and supply good quality grass for livestock. Eleven species — including *Medicago sativa, Melilotus albus, Onobrychis viciaeofolia, Astragalus adsuragens, Panicum virgatum,* and *Andropogon geraidii* –were found to be drought tolerant and able to complete their full life cycle in the Taihang mountains. Most of the leguminous species studied needed 120 days to complete their cycle and produce seed. In contrast, most forage herbs in the grass family need 150 days to complete their growth cycle. The growth period of the introduced species was longer on average

Box 11.1

High-value Medicinal Plants for Farming in Forests and on Marginal Mountain Slopes in the Taihang Mountains

Ginseng	*Villous amomum*
Amur cork	*Cinchona ledgeriana*
Eucommia	*Perilla frutescens*
Magnolia	*Schizonepeta tenuifolia*
White aster	*A. membranaceus*
Nackberry lily	*Cassia tara*

than that of local grasses, which grow for three to four months during the rainy season to use residual moisture.

The types of land used for forage production were barren slopes, forest, orchards, and terraces. This practice helped improve the soil fertility of the forests, orchards, and barren lands, as shown in Table 11.4.

Table 11.4: The Influence of Herbage on Soil Fertility Three Years after Plantation

Herbage	*Medicago sativa*		*Melilotus albus*		*Onobrychis viciaeoflia*	
	herbage	control	herbage	control	herbage	control
Organic matter (%)	0.84	0.71	1.07	0.94	0.82	0.75
Total N (%)	0.084	0.011	0.113	0.082	0.076	0.054
Available N ($mg.kg^{-1}$)	51	37	63	43	48	36
Available P ($mg.kg^{-1}$)	1.0	1.0	1.5	1.0	1.0	0.5
Available K ($mg.kg^{-1}$)	128	126	113	123	170	152

The plantation of forage herbs greatly improved the biomass of terraced and old deserted sloping farmlands. It was observed that the annual biomass of three-year old *Medicago sativa* reached 9.9 t/ha, and the biomass of *Miliotus officinalis* reached 13.7 t/ha, ten times more than the biomass of other native grasses. In the fourth year, when crops were planted on this land, crop productivity on the deserted marginal lands was 4.8 t/ha for wheat, 0.6 t/ha for cotton, and 0.9 t/ha for soybean.

Agrobiodiversity and Economic Benefits of Intercropping on Mountain Farmlands

Fourteen different types of intercropping system in addition to grape and wheat intercropping were developed in the experimental region. These 14 systems can be divided into five types: fruit trees or economic trees intercropped with crops; fruit trees or economic trees intercropped with economic plants; fruits tree intercropped with vegetables; fruit trees or economic trees intercropped with Chinese medicinal plants; and fruit trees or economic trees intercropped with forage herbs. Tables 11.5 to 11.8 show the economic benefits of intercropped systems compared to those of the same crops grown as monocultures. It is clear that the economic benefits from all 14 kinds of intercropping systems were higher than from any trees or plants planted as monocultures. Both the economic benefits and crop diversity were maintained.

Socioeconomic Benefits of the Experiment.

The introduction of economic plants created opportunities for forest and agroforestry systems suited to the site conditions of local farmers. This approach

Table 11.5: **Comparison of Economic Benefits of Fruit Trees and Crops Grown in an Intercropping System or as Monocultures**

Inter cropping Model	Area (ha)	Age of tree (years)	Yield of fruit (kg)	Yield of crop (kg)	Economic output (*yuan*)	Economic results (*yuan*/ha)
Apricot + wheat	0.20	5	750	200	1210	6050
Walnut + wheat	0.135	20	170	200	1010	7575
Peach + sweet potato	0.135	44	900	1000	1100	8250
Wheat	0.5			1350	1080	2160
Apricot	0.4	5	1600	-	2240	5600
Walnut	0.04	20	25	-	250	6250
Peach	0.30	4	2250	-	2250	7500

* There are 8.28 *yuan* to the US Dollar.

Table 11.6: **Comparison of Economic Benefits of Fruit Trees or Vines and Economic Crops Grown in an Intercropping System or as Monocultures**

Intercropping model	Area (ha)	Tree spacing (m^2)	Age of tree/vine (years)	Yield of fruit crop (kg)	Yield of crop (kg)	Economic output (*yuan*)	Economic results *yuan*/ha
Grape and peanut	0.02	1x4	5	300	15	390	19,500
Grape and mung bean	0.02	1x3	5	420	12	540	27,000
Apple and soybean	0.04	6x6	18	440	18	588	14,700
Peanut	0.20				648	1296	6,480
Mung bean	0.10				120	480	4,800
Soybean	0.30				630	1890	6,300
Grape	0.03	1x3	5	400		480	16,000
Apple	0.20	6x6	18	2230		2676	13,380

Table 11 7. **Comparison of Economic Benefits of Fruit Trees or Vines and Vegetable Crops Grown in an Intercropping System or as Monocultures**

Intercropping model	Area (ha)	Tree spacing (m^2)	Age of tree/vine (years)	Yield of fruit crop kg)	Yield of vegetable (kg)	Economic output (*yuan*)	Economic results (*yuan*/ha)
Grape &potato	0.25	1x4	5	450	100	560	21,000
Grape and onion	0.25	1x4	5	400	60	516	19,350
Apple and garlic	0.02	3x4	5	400	40	488	24,400
Potato	0.02				290	58	2,900
Onion	0.01				70	42	4,200
Grape	0.40	1x4	5	5400		6480	16,200
Apple	0.40	3x4	5	6500		7800	19,500

has been successful in combining the objectives of environmental improvement and income generation opportunities for farmers. By the end of 1995, the technologies developed had been adopted in the surrounding 20 villages and the farmers' average annual income had reached 673 *yuan* per capita (a rise to US$ 116 from US$ 43). Local government institutions were made aware of this

Table 11.8: Comparison of Economic Benefits of Fruit Trees and Chinese Medicinal Plants Grown in an Intercropping System or as Monocultures

Intercropping model	Area (ha)	Age of tree (years)	Fruit yield (kg)	Medicinal plant yield (kg)	Econom ic output (yuan)	Economi c result (yuan/ha)
Grape and *rhizome* of windweed	0.02	5	260	14	424	21,200
Grape and black-cherry lily	0.02	5	280	15	456	22,800
Apple and rhizome – large-headed atractylodes	0.03	5	380	10	536	17,867
Rhizome of windweed.	0.01			19	152	15,200
Black-cherry lily	0.02			42	336	16,800
Grape	0.03	5	360		432	14,400
Apple	0.20	5	1980		2376	11,880

successful approach to environmental rehabilitation (the development of economic forest) and several training programmes were organized to popularise it. More than 3,500 farming families have visited the experimental station so far. It is expected that the economic benefit resulting from technology transfer from this station will reach 0.1 billion *yuan* at the end of this century.

Some Common Issues

The study by Shijiazhuang Institute of Agricultural Modernisation demonstrated that promoting economically suitable options — including both local and exotic plant genetic resources — for rehabilitating degraded land can enhance agrobiodiversity. Of 348 species and varieties tested, a total of 50 species was found to be successful. The study raised the issue that afforestration for the sake of forestry *per se* is not an attractive option for farmers as they do not see any immediate economic benefits from such plantations. Providing the option of cash generating crops combined with economically useful tree species can be a good strategy to motivate community participation. High-value medicinal plants (woody or herbaceous) are often intercropped with an established timber plantation four to five years after first pruning. This agroforestry system can help balance the conflict between the long-term economic benefit of timber production and medium-term opportunities for livelihood. It can also help in meeting the increasing demand for high value medicinal plants. The system can be seen as an alternative method for maintaining agrobiodiversity through the participation of communitiies, because farming communities see the benefit of maintaining and cultivating high-value indigenous medicinal crops.