Chapter 5

Apple Farming and Pollination Issues in Maoxian Valley, China

Farming in Maoxian Valley

Maoxian Valley is located in Aba Prefecture in the north-west of Sichuan Province of China. The population of the county is about 91,200, the altitude varies from 890 to 4984 masl, and the total land area is 4064 km². Only about 11,000 ha of the total land area (2.6%) is counted as arable (agricultural) land. The remainder is forest (27%), shrub land (36%), meadows (22%) and dry barren land. Orchards are planted on about a quarter of the arable land, that is about 0.7% of the total land.

Agriculture is the main occupation of over 90% of the working population. Farms are mostly small or marginal, with on average less than half a hectare of land per family. Basic food crops include maize, wheat, potatoes, soybeans, and horse beans. Cash crops are grown on some 7,330 ha of land and include apples (2830 ha), Chinese prickly ash (3,000 ha), and off-season vegetables such as tomatoes, capsicum, and cabbage (1,500 ha). Other fruit crops are also planted to a limited extent including plums, peaches, pears, and grapes.

The history and scale of apple farming

Apples are the main cash crop and account for more than 80% of total farm income in the county. Apple farming started in Maoxian Valley in 1946 with 400 trees of 10 varieties. By 1953 there were 4000 trees of 46 varieties, and by 1985 some 200,000 trees covering 730 ha of land. Large-scale apple planting during the 1980s made apples an important crop in the farm economy of the valley. In 1998, apple orchards covered about 2830 ha of land, and produced around 30,000 tonnes of apples per year (Figure 5.1) with a total value of about 40 million yuan (US $4.2 million). Apples from this region, known as 'Maowen apples', are famous

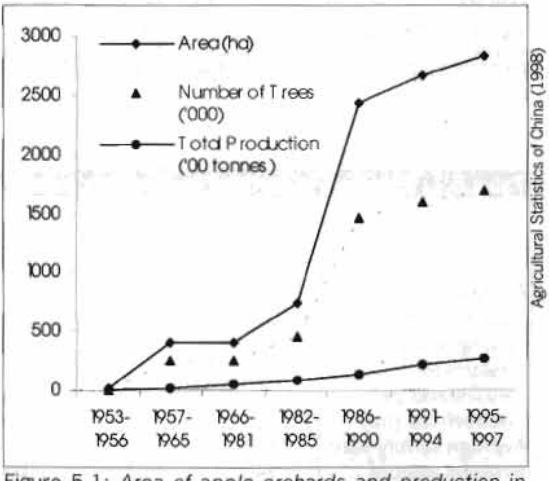

Figure 5.1: *Area of apple orchards and production in Maoxian county*

for their high quality and are sold in Chinese markets in places as far away as Beijing, Tianjing, Guangzhu, and Hong Kong. Nowadays, they are also exported to Russia and a few other southeast Asian countries.

In 1985 the Chinese Academy of Horticulture organised a national contest on apples, the Delicious varieties of apple won first prize for quality. As a result, the farmers in Maoxian County started replacing all other apple varieties with Delicious varieties. The apple trees planted in the large-scale plantations of the 1980s were more than 90% Royal Delicious. When these plantations started bearing fruit, they showed very low productivity per acre, and the average productivity for the county started to decline. By 1990, apple productivity had dropped from about 13.5 tonnes per ha in 1985, to 6.2 tonnes per ha (that is, by about 50%). Exploratory studies showed that insufficient pollination was one of the main factors for this decline in productivity.

The Survey Findings

The survey in Maoxian Valley covered 100 apple-farming families in 6 villages at altitudes ranging from 1500 to 1850 masl (Chapter 3). About 65% of the apple orchards are located on the flatter valley bottom between 1500 and 1700, the area most suitable for apples; another 30% are located on gentle slopes between 1700 and 2000m; and the remainder (5%) are above 2000m. Sixty per cent of the surveyed farmers were in the lower area and 40% in the higher (Table 3.2).

Farmers and the farm economy

Table 5.1 summarises the general agricultural parameters in the selected villages. The average landholding size ranged from 0.2 to 0.7 ha among the different villages with an overall average of 0.4 ha. In all the villages, farmers were also using so-called wasteland to grow Chinese prickly ash (on average 0.2 ha per household), the next most important cash crop in the county after apples.

The average annual income per household in Maoxian County was US $ 1200. It varied from as low as US$ 740 to US$ 1760 in different villages (Table 5.1).

Table 5.1: The state of farming in Maoxian Valley (surveyed farmers)

	Village						
	Suangma	Mati	Dagou Fengyi	Jingzhou	Zhongqu	Jincu Nanxin	Average
Average arable land per household (range) (ha)	0.6 (0.27–1.0)	0.7 (0.13–1.13)	0.3 (0.12–0.73)	0.2 (0.07–0.39)	0.3 (0.13–0.8)	0.3 (0.09–0.47)	0.4 (0.07–1.13)
Reclaimed wasteland per household (ha)	0.2	0.2	0.2	0.3	0.3	0.2	0.2
Average family size	5.2	6.1	5.4	4.4	5.4	4.4	5.1
Average annual household income (US$)	940	1410	1060	740	1760	1290	1200

Apple farming

The basic parameters of apple cultivation are summarised in Table 5.2. The average size of apple orchard per household varied among the villages from 0.1 ha in Suangma to 0.3 ha in Dagou Fengyi, with an average of 0.2 ha. On average, the farmers were using two-thirds of their arable landholdings for apple trees with percentages ranging from 92% in Dagou Fengyi to only 21% in Suangma (Figure 5.2). The actual number of trees per household varied from 91 in Jingzhou to 220 in Dagou Fengyi, and the average annual production from 2078 kg in Suangma to 8192 kg in Daguo Fengyi (Table 5.2). There was a lower yield in Suangma and Mati because apple farming had been introduced more recently and many of the trees were not yet productive. Apples were the main source of farm income in four villages, where they contributed between two-thirds and three-quarters of the total (Table 5.2). The price that apples commanded also varied between the villages, with lower prices at higher altitudes – from US$ 0.11 per kg in Suangma to US$ 0.16 per kg in Zhongqu and Jincu Nanxin (Table 5.2). This may reflect the higher transportation costs from higher altitudes.

The most popular varieties were Royal Delicious, Golden Delicious, Red Delicious, and Fuji Red; almost 90% of all apple trees in the region are Royal Delicious, and only 5-7% are Golden Delicious – the main pollinizer for Royal Delicious. The overall pollinizer proportion varied from 16% in Suangma to 6% in Jincu Nanxin (Table 5.2).

Farmers in the highest altitude village of Suangma used less pesticide than those at lower altitudes, with an average minimum of 4.2 sprays per season compared to 10.5 sprays in Zhongqu (Table 5.2). The insecticides used included

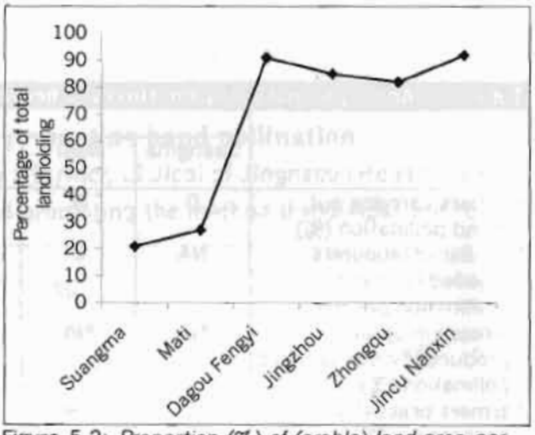

Figure 5.2: *Proportion (%) of (arable) land area per household under apple orchards*

Table 5.2: Apple cultivation by surveyed households (HH)

	Village						
	Suangma (1850m)	Mati (1670m)	Daguo Fengyi (1720m)	Jingzhou (1670 m)	Zhongqu (1530 m)	Jincu Nanxin (1500 m)	Average of all villages
Average size of apple orchard per HH (ha)	0.1	0.2	0.3	0.2	0.3	0.2	0.22
Number of apple trees per HH	113	134	220	91	181	173	152
Pollinizer proportion (%)	16	12	11	10	8	6	11
Average annual apple yield per HH (kg)	2078	2853	8192	3568	7405	5714	4970
Average contribution of apple crops to HH income (%)	26	23	64	67	67	70	53
Price per kg (US $)	0.11	0.12	0.10	0.14	0.16	0.16	0.13
Number of pesticide sprays per year	4	8	9	9	11	10	9

omechoale, phoxim, dichlorvos, dicofol, and methyl-parathion. Farmers also sprayed pesticides on vegetable and rapeseed crops that were cultivated under the apple trees.

Apple pollination management practices

The parameters of apple pollination in the six villages are summarised in Table 5.3 and Figure 5.3. In the lower altitude villages, the apple trees were mostly pollinated by hand, whereas at higher altitude they were mostly naturally pollinated. In the two lowest villages, all the farmers hand pollinated each and every flower inflorescence on all the apple trees. At higher altitudes the proportion of pollinizer trees was higher and pesticide use was lower (Table 5.2). Stationary beekeeping with *Apis cerana* was also considerably more common in higher altitude villages, around a quarter of all farmers kept bees compared with less than 10% in the lower altitude villages (Table 5.3). Taken together the results show that hand pollination was most commonly practised in the lower altitude villages where pollinizer proportions were low, beekeeping less common, and pesticide use greater; and natural pollination was relied upon in the higher altitude villages where pollinizer proportions were higher, beekeeping more common, and pesticide use

Table 5.3: **Apple pollination by the surveyed households**

	Village						
	Suangma	Mati	Dagou Fengyi	Jingzhou	Zhongqu	Jincu Nanxin	Average of all villages
Farmers carrying out hand pollination (%)	0	6	0[1]	82	100	100	48
Number of labourers needed for hand pollination per HH	NA	0	NA	12	37	31	27
Increase in apple productivity due to hand pollination (%)	NA	NA	NA	51	46	39	45.3
Farmers practising beekeeping (%)	22	39	23	6	10	7	18

[1]5% of farmers sprayed honey on apple flowers

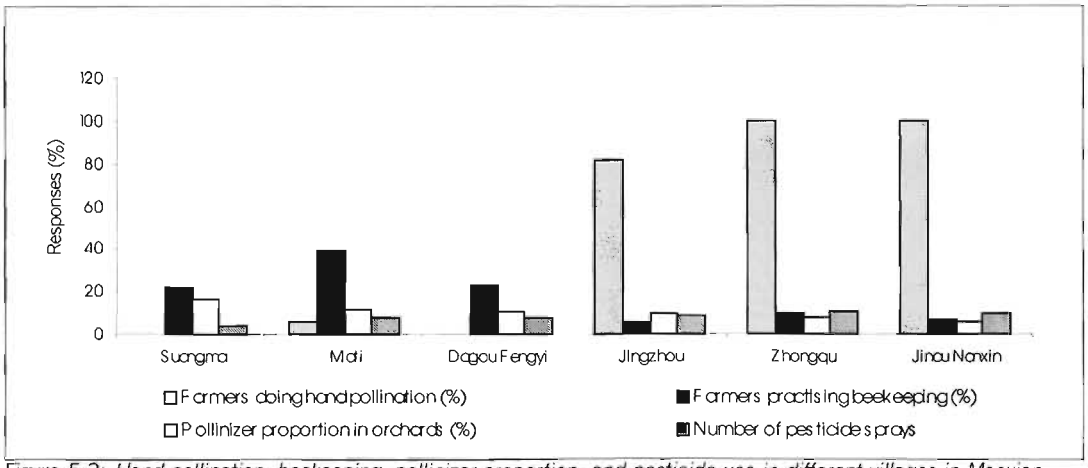

Figure 5.3: *Hand pollination, beekeeping, pollinizer proportion, and pesticide use in different villages in Maoxian County (percentage of responses)*

less (Figure 5.3). The interviews with farmers suggested that for those who used it, pollination by hand increased apple productivity by 40-50% (Table 5.3).

Hand pollination is a community effort in many of the villages. Apple flowering starts at lower altitudes and progresses upwards. As farmers at the higher altitudes do not pollinate their apples by hand anyway, they are mostly free at the time the apples bloom in the lower areas and are hired to hand pollinate the apple crops. The average number of additional labourers hired by farmers in the survey varied from 12 to 37 per family in the different villages and was related to the average number of trees per household (Table 5.3). Some larger families pollinated their apple orchards themselves.

There were some differences in the way that hand pollination was practised in the Shimla Hills of Himachal Pradesh and in Maoxian Valley. In the Shimla Hills the farmers pollinated 20-50 flowers per branch whereas in Maoxian Valley it was three out of five flowers in each apple inflorescence, and in the Shimla Hills the process was carried out only once in a season whereas in Maoxian Valley it was repeated at least three times to cover late flowering.

Hand-Pollination

The role of local government institutions in promoting hand pollination

The practice of hand pollination was introduced by a farmer, Li Jicai of Jinghzou (He et al. 1998). Noting his success, the county government started promoting the method throughout the county. Field experiments to standardise the technique were completed in 1990 and farmers were given training in 1991. At that time only a few farmers accepted the technique. As the impact of hand pollination became apparent, other farmers introduced it. In 1991, 17% of farmers in the lower altitude villages (Jinzhou, Zhongu and Jincu Nanxin) knew about hand pollination and 10% practised it; by 1997 all farmers were aware of its importance and 92% were using it for pollination of about 2000 ha of trees (Figure 5.4). The county government took no steps to raise awareness about or promote the use of beekeeping for pollination.

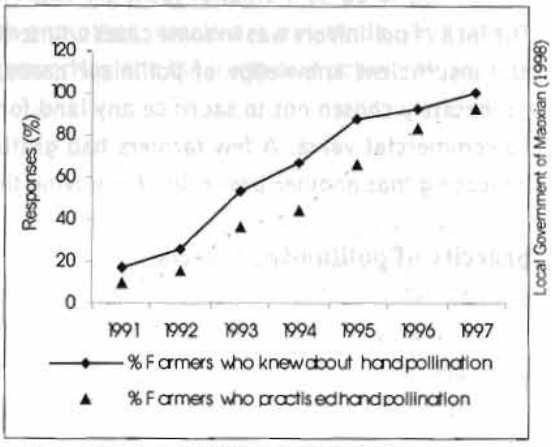

Figure 5.4: *Hand pollination in Maoxian County (farmers in Jingzhou, Zhongqu and Jincu Nanxin villages only)*

Cost-benefit analysis of apple pollination by hand and by honeybees

Hand pollination of apples and other crops (such as pears and tomatoes) is a massive effort. Table 5.4 shows a rough cost-benefit analysis of hand pollination and bee pollination as practised in the valley (additional monetary costs only, i.e., ignoring input of labour by family members and costs of keeping own bees). Hand pollination is a laborious and time-consuming method. A small farmer owning only 0.2 ha of apple farm will need the services of about 25 person days, in addition to his own family, to pollinate his apple crop, which means an outlay of US$ 60 for skilled labour

Table 5.4: **Cost-benefit analysis of pollination by hand and by honeybees**	
General Data	
Average landholding size (ha)	0.2
Average apple yield (kg) per household	4970
Price per kg (US $)	0.13
Hand Pollination	
Labourers needed (person days)	25
Cost of labourers @ US $ 2.40 per labourer per day	US$ 60
Honeybee Pollination	
Number of honeybee colonies needed @ 5 colonies per ha	1
Cost of hiring honeybees @ US $ 7.5 per hive	US$ 7.5

('farmer pollinators'). In theory, the same apple crop could be pollinated by one colony of honeybees. The rental fee for a honeybee colony in the county is only about US $7.50.

Why Don't Apple Farmers Use Honeybees for Pollination?

Lack of appropriate ratio of pollinizer varieties

One important factor that compels farmers to pollinate by hand is the lack of pollinizer trees. The great majority of trees are of the self-incompatible Royal Delicious variety; in theory each Royal Delicious tree should have a pollinizer tree near it so that pollen is available to its flowers (Gautam et al. 1994; Partap 1998; Partap and Partap 2000; Verma and Jindal 1997). The standard requirement is for 20% of trees to be pollinizers (see Chapter 2), but at lower altitudes farmers had only 6-10% of pollinizer trees (Table 5.2). If there are few pollinizers, then insects can only play a limited role in pollination.

The lack of pollinizers was in some cases unintentional, farmers and government extension agencies had insufficient knowledge of pollinizer needs, in others farmers with small landholdings had deliberately chosen not to sacrifice any land for pollinizer varieties because they were of little or no commercial value. A few farmers had grafted pollinizers onto the trees of the main variety, indicating that another possibility for solving the problem is being recognised.

Scarcity of pollinating insects

The second important factor that causes farmers to resort to hand pollination is the scarcity of pollinating insects. Both the diversity and the total populations of natural insect pollinators have declined in the region. There are several reasons, including loss of food and nesting habitats and the indiscriminate use of pesticides. After 1980, when apples became the lead cash crop of the county, the use of pesticides increased rapidly, killing many natural pollinators, (Table 5.3). In theory, these wild species could be replaced by honeybees kept in hives. Beekeeping as such is common in Maoxian County (both stationary beekeeping with *Apis cerana* and migratory beekeeping with *Apis mellifera*). Many farmers were aware that honeybees could play an important role in apple pollination and had wanted to hire honeybee colonies for this purpose, offering food and fuelwood in return for using the bees. But the most commonly used insecticides are also all highly dangerous to bees and beekeepers were not interested, preferring to keep their hives a few kilometres away from any apple orchards in order to avoid the bees being killed by pesticides. Five of the interviewed beekeepers stated that they would only rent their honeybees for apple pollination if the farmers did not spray

pesticides when the bees were in the orchard and if they paid a cash rental fee of around US $ 7-8 per colony per season.

Frequent occurrence of bad weather conditions

The third factor leading farmers to pollinate their apples by hand was the frequent occurrence of bad weather conditions during flowering. Apple pollination is adversely affected by bad weather conditions (Verma et al. 1990) for a number of reasons. Low temperatures and rain affect the foraging activities of insect pollinators, rainfall on the flowers can wash away the pollen, and hailstorms can damage the flowers. Local meteorological data show that unfavourable climatic conditions have occurred almost every other year over the past decade.

Summary

Thus there are a number of reasons why farmers rarely used honeybees specifically for pollination. Awareness about the use of honeybees was poor; the research and development institutions did not promote the use of honeybees so the farmers did not know about it, and the county government promoted hand pollination. The biggest constraint, however, was the excessive and indiscriminate use of pesticides. Even where farmers wanted to use bees they were unable to rent them as the migratory beekeepers were unwilling to expose their colonies to the dangers of insecticides. There is a need to set up a formal rental system for honeybees for pollination, to fix rental fees that are acceptable to both farmers and beekeepers, and to ensure that no insecticides are sprayed during flowering.

Overall, the farmers believed that hand pollination was the most reliable method of pollination under adverse weather conditions when honeybees and other insects are not flying, and that it ensured maximum pollination when the pollinizer proportion and the number of pollinating insects are low.

Summary of Issues

The survey results showed that the decline in apple productivity in Maoxian County was caused by insufficient or even total pollination failure. Farmers were aware of it and had understood the significance of ensuring pollination to maintain yield. Hand pollination was the most common practice adopted and had turned into a massive exercise in which every family member (men, women, and children) was involved. Various cooperation mechanisms had also evolved among farmers for sharing labour and skills. Beekeeping was more common at higher altitudes, but there were no beekeepers renting honeybee colonies to the farmers, even though this would have been cheaper for farmers than hand pollination. The two main reasons appeared to be that the practice was not being promoted and that the beekeepers were hesitant to rent out their honeybee colonies because of the excessive use of pesticide sprays on the apple trees.

Even though hand pollination is the most reliable method of ensuring apple pollination, it is unlikely to be sustainable as a long-term practice, largely because of increasing labour scarcity and costs. In mountain areas where agriculture is diversifying towards new cash crops, there is a need to raise awareness among people and local research and extension systems, not only about the significance of managing pollination but also about using honeybees for pollination as an alternative

to the prevalent practice of hand pollination. The risk of pesticides can be minimised through judicious use as well as by adopting integrated pest management practices, and the proportion of pollinizers raised by grafting where planting of new trees is inappropriate or undesirable.