Bamboo Management, Economics, and Finance:
Evidence from Moso Bamboo Farmers in China[1,2]

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Abstract

Moso bamboo is the single most important bamboo species in China, accounting for 74% of China's bamboo forest area, as well as the third most important source of timber in China. Both bamboo shoots and bamboo stems are harvested as valuable products: bamboo shoots are a traditional food source, and bamboo stems are used as timber for paper making, flooring, and construction. In this paper we describe and discuss bamboo management strategies, economics, and finance. We also discuss and draw insights from interviews we conducted of Moso bamboo farmers in China regarding their bamboo stem and shoots harvesting behavior and financial status.

Keywords: bamboo forest management, Moso bamboo, China
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1. Introduction

The world's forest resources are in decline as human populations continue to grow and the demand for food and land increases (FAO, 2005; Matthews, 2012; FAO, 2015). The need for sustainable forest management is particularly acute in developing countries such as China, which ranks among the top countries in terms of total forest resources, accounting for 25% of the world demand for forest products, but only 5% of the world's forest area (China Forestry and Grassland Administration, 2018), and is a country where deforestation is rampant (Démurger, Hou, and Yang, 2009).

China has 208 million hectares of forest area, covering 21.63% of total area of the country and constituting a total stock volume of 15,173 million cubic meters. China ranks among the top countries in terms of total forest resources, accounting for 25% of the world demand for forest products, but only 5% of the world's forest area (China Forestry and Grassland Administration, 2018).

China has the world's most copious bamboo forest resources, with more than 500 bamboo species in 39 genera spanning 6.01 million hectares of bamboo forest. Bamboo (*Bambusoideae*) grows faster compared to other forest types (Wei et al., 2018), which is consistent with the preservation- and restoration-orientation of China's forest management policies since the 1990s (Démurger, Hou, and Yang, 2009). Eighty-nine percent of China's bamboo forests are located in eight provinces: Fujian, Jiangxi, Zhejiang, Hunan, Sichuan, Guangdong, Guangxi and Anhui ("China Forestry and Grassland Administration", 2018). Of the bamboo forest resources in China, 6.6% are in state forests, 51.4% are in collective forests, and 42.0% are in private forests (Démurger, Hou, and Yang, 2009).

Moso bamboo (*Phyllostachys edulis*) is the single most important bamboo species in China, accounting for 74% of China's bamboo forest area ("China Forestry and Grassland Administration", 2018), as well as the third most important source of timber in China. Both bamboo shoots and bamboo stems are harvested as valuable products: bamboo shoots are a traditional food source, and bamboo stems are used as timber for paper making, flooring, and construction (Fu, 2001).

Optimal Moso bamboo management is a complex dynamic problem (Wu et al., 2025a). Moso bamboo forest management involves making decisions about the timing and quantity of bamboo stem harvests and bamboo shoot harvests. Both bamboo stems and bamboo shoots are

products that are sold on the market. Bamboo shoots prices vary day to day and are hard to predict, while bamboo stem price does not vary much over the course of a year. Bamboo shoots grow annually from a bamboo plant's underground rhizomes. Owing to their tender taste and to difficulties in harvesting underground shoots, winter shoots – which are young bamboo shoots that are just beginning to grow underground during the winter months – have a higher market price than the older spring shoots that emerge above ground during the later spring months. Bamboo shoots grow into bamboo plants after the end of spring shooting (Shi et al., 2013). While winter shoots are more expensive than spring shoots, both winter shoots and spring shoots are more expensive than bamboo stem. Bamboo stems continue to grow each year until age 4-5 years (Zhang et al., 2014; Zhuang et al., 2015), while bamboo shoots only grow within a year. The harvesting of bamboo stems entails cutting down the bamboo plant, while the harvesting of bamboo shoots does not.

There are several trade-offs involved in determining the optimal shoots harvesting strategy that arise from uncertainty and the interdependence of shoots and stem. Reasons to harvest shoots sooner rather than later include: high prices, low costs, and uncertainty over survival. Reasons to delay shoots harvest, include: uncertainty over prices, and allowing shoots more time to grow. Reasons not to harvest shoots at all include: low prices, high costs; allowing shoots to grow into bamboo stem at the end of the year; and uncertainty over precipitation, which affects how many shoots will grow the following year from any stem that grow from unharvested shoots the previous year (Wu et al., 2025a).

Likewise, there are several trade-offs involved in determining the optimal bamboo stem harvesting strategy. Reasons to harvest stem sooner rather than later include: high prices and low costs. Reasons to delay bamboo stem harvest include: low prices, high costs; allowing bamboo stem more time to grow; allowing shoots to grow annually from the bamboo plant; and uncertainty over precipitation, which affects how many shoots will grow from the stem remaining at the beginning of the year (Wu et al., 2025a).

Various management styles have been found in bamboo forests in Asia, and the decisions of bamboo farmers can be complex and hard to understand (Yen, 2015). The bamboo stem harvests and bamboo shoot harvests decisions made by Chinese bamboo farmers may be unsustainable, leading to profit loss and a deterioration of the bamboo forest resource. The bamboo stem price has decreased significantly in recent years, and some bamboo plants have been left unharvested

when matured due to high harvest cost. In contrast, winter shoots have sometimes been over-harvested for high profit, leaving too few shoots for future bamboo forest development.

We contribute to the literature on optimal forest management (Faustmann, 1849; Wicksell, [1901] 1934; Samuelson, 1976; Newman, 1988; Jackson, 1980; Chang, 1983; Chang, 1981; Hall, 1983; Berck, 1981; Bowes, 1983; Calish et al., 1978; Hartman, 1976; Nguyen, 1979; Strang, 1983; Chang, 1982; Klemperer, 1979; Pearse, 1967; Rideout, 1982; Ollikainen, 1991; Bare and Waggener, 1980; Gregersen, 1975; McConnell et al., 1983; Hardie et al., 1984; Newman et al., 1985; Nautiyal and Williams, 1990; Chang, 1998; Deegen et al., 2011; Arimizu, 1958; Amidon and Akin, 1968; Kilkki and Väisänen, 1969; Hool, 1965; Hool, 1966; Amidon and Akin, 1968; Amidon and Akin, 1968; Brodie et al., 1978; Brodie and Kao, 1979; Chen et al, 1980; Ritters et al., 1982; Tyler, Macmillan, and Dutch, 1996; Ritters, 1982; Haight, 1985; Yousefpour and Hanewinkel, 2009; Buongiorno, and Gilless, 2003; Kant and Alavalapati, 2014; Wu et al., 2025a; Wu et al., 2025b). Wu et al. (2024) provide a recent review of the literature on optimal forest management.

2. Background on Moso Bamboo in China

2.1. Forests and forest policy in China

China's forest deficiency results from a combination of various factors. Historically, China was a feudal society that relied on the brutal extraction of natural resources. Land cultivation in China started thousands of years ago, and since then there has been a continued conflict between forest and crop cultivation. Firewood collection, charcoal making, land reclamation, brick making, and house construction contributed to deforestation in the preindustrial periods (Fang and Xie, 1994). It was not until industrialization, however, when massive deforestation took place. The Great Leap forward (1958-1962) campaign destroyed forests by popularizing the usage of homemade furnaces. Even after the campaign, deforestation intensified, providing cheap logs for industrialization (Wang, Van Kooten, and Wilson, 2004). During the transition from a central planning system to a market economy, local households had insecure ownership rights over tress, leading to forest clearing and deforestation (Démurger, Hou, and Yang, 2009).

The forest sector acted as a base for Chinese industrial development in the first several decades after 1949. Although there are experts who appealed to ecosystem protection (Wang, Van

Kooten, and Wilson, 2004), there was little focus on forest stock preservation. Prior to 1982, forest policies in China defined the priority of forest management was timber production (Démurger, Hou, and Yang, 2009). Although the China Forestry Administration was in place, there was no formal legislation. It was not until 1979 that the first forest law got passed and became effective in 1984 (Wang, Van Kooten, and Wilson, 2004). In the l990s, China started its transition to preservation and restoration-oriented forest management policies. Six major forestry conservation, restoration, expanding, and commercially developing programs were launched in order to recover and better manage forest resources in China (Démurger, Hou, and Yang, 2009).

2.2. Bamboo stem and shoot growth

Bamboo (*Bambusoideae*) is distributed mostly in tropical areas, subtropical areas, and temperate zones in Asia. They survive even at 4000 meters elevation from sea level (Scurlock, Dayton, and Hames, 1999). There are 107 genera and 1300 species of bamboo worldwide (Zhu, 2001). Bamboo grows faster compared to other forest types (Wei et al., 2018), which is consistent with the preservation- and restoration-orientation of China's forest management policies since the 1990s (Démurger, Hou, and Yang, 2009).

Moso bamboo (*Phyllostachys pubescens*) is the single most important bamboo species in China, accounting for 74% of China's bamboo forest area ("China Forestry and Grassland Administration", 2018). Moso bamboo distributes mostly in subtropical provinces including Fujian, Hunan, Zhejiang, and Jiangxi. The mean annual temperature where Moso bamboo grows well varies from 15 to 21°C (59 to 69.8°F), and the mean temperature of the coldest month is 1 to 12°C (33.8 to 53.6°F). Annual precipitation higher than 800mm (31.5 inches) and soil fertile loam deeper than 60cm (23.5 inches) with pH of 4.5 to 7.0 are ideal for Moso bamboo growth. Extreme temperature, precipitation, and soil conditions influence bamboo shoot growth for different areas (Fu, 2001).

A bamboo growth year begins in September with winter shooting. The number of bamboo shoots at the beginning of the bamboo growth year is positively correlated with the number of bamboo stem: the more bamboo stem, the more rhizomes there are underground, and the more bamboo shoots that can grow (Li et al., 2016; Zhang and Ding, 1997). The number of bamboo shoots is also positively correlated with precipitation in July and August of the previous bamboo growth year, when bamboo shoots are being formed (Zhang and Ding, 1997).

As long as the shoots are underground and have not emerged above ground, they are called winter shoots. Winter shoots remain dormant during the coldest winter days in January and February, and emerge above ground as spring shoots in March when temperature rises. Due to their dormancy, the nutrient contents of winter shoots do not change by much in these two months (Su, 2012). Winter shoots can be harvested and sold on the market for a high winter shoots price until they emerge above ground and start to be called spring shoots. The traditional bamboo management guidance is to avoid harvesting too many winter shoots before spring shoots emerge, in order to foster a new bamboo forest (Forestry Department of Hunan Province, 2008).

Bamboo shoots either degenerate, are harvested, or are left in the ground and grow into a newly grown bamboo stem (personal communication, bamboo specialist at Zhejiang Provincial Key Laboratory of Bamboo of Zhejiang Provincial Academy of Forestry, August 2018). More than half of the shoots will degenerate and die naturally before they grow into bamboo plants (Jiang, 2007).

Bamboo shoots grow into a bamboo plant after the end of spring shooting (Shi et al., 2013). The number of newly grown bamboo is the number of surviving bamboo shoots minus number of shoots harvested. Moso bamboo stems reach their maximum biomass at age 4-5 years (Zhang et al., 2014; Zhuang et al., 2015), do not increase significantly in biomass after 4.62 years (Zhuang et al., 2015), and mature at age 5-6 years (Yen and Lee, 2011). As a consequence, bamboo farmers usually clear cut sixth-year-old bamboo rather than wait until they grow into seven-year-old ones (personal communication, bamboo specialist at Zhejiang Provincial Key Laboratory of Bamboo of Zhejiang Provincial Academy of Forestry, August 2018).

2.3. Bamboo management

The harvesting of bamboo shoots is a natural process of thinning since without human intervention, more than half of the shoots will degenerate and die naturally before they grow into bamboo plants. Shoots harvesting is thus a thinning activity that takes these weak shoots out before their death (Jiang, 2007). Harvesting one shoot eliminates one future bamboo plant from the beginning. Harvesting shoots does not necessarily reduce total bamboo biomass in the future, however, since thinning creates more space for other bamboo plants left in the ground to grow.

In forest management in the United States, forest thinning (silviculture) generally produces low quality logs that incur a cost due to their low market value. A unique feature of bamboo shoot

thinning is that by harvesting bamboo shoots, bamboo farmers are also able to sell shoots as a by-product with a high market price.

Various management styles have been found in bamboo forests in Asia, and the decisions of bamboo farmers can be complex and hard to understand (Yen, 2015). Chinese bamboo farmers generally follow a pattern of intensively harvesting shoots when they first emerge, and then preserving the remaining shoots for later bamboo growth. In Zhejiang Province in China, bamboo forest harvest decisions and shoots harvest decisions are made according to on and off years, with guidance from biologist and forestry specialists. "On" years and "off" years are defined based on the biological growth of bamboo plants. An "on" year is a year when there is a massive emergence of bamboo shoots, and less leaf loss for a bamboo plant. An "off" year is a year with less shoots emergence and more leaf renewing, and normally comes in turn with an on year. Shoots harvest, especially winter shoots harvest, takes place during on years, when there is a massive emergence of bamboo shoots. In order to create enough growth space for shoots to emerge, and to save space for the shoots harvest before possible decaying, bamboo stem harvests take place during on years as well. Every time a stem harvest decision is made, all mature bamboo stems are clear cut for the whole field. Due to this clear-cut pattern, massive shoots emergence and the clear cutting of mature bamboo take place simultaneously in the on year. When bamboo stems are harvested during an on year, the number of shoots the following off year will be lower. During an off year, relatively fewer shoots are harvested, and little stem cutting takes place.

2.4. Bamboo market

The bamboo market in China is arguably characterized by perfect competition. The number of bamboo farmers in China is quite high. There were 7.14 million bamboo farmers in 2010 (International Bamboo and Rattan Organisation, 2012). In Anji County of Zhejiang province alone, there were approximately 110,000 farmers growing bamboo and another 11,000 people working in the bamboo-processing industry in the county in 1999 (Pérez et al., 1999). Bamboo farmers in Zhejiang province are small peasants who own a relatively small amount of land per family. The average land area managed by a family in Anji County is 21.2 mu, of which 14.9 mu (70%) is allocated to bamboo plantations (Pérez et al., 1999).

Bamboo management standards for ensuring an appropriate tree cover and to prevent degradation of the resource stock vary by province and sometimes also by county, and are

suggested by the production cooperatives. Farmers' cooperatives in China are owned and operated by their members, and are strongly committed to the development of the local communities (Chen and Scott, 2014). In the agricultural sector, cooperatives help to improve the productivity and living conditions of smallholder farmers by facilitating access to markets, credit, technology and local off-farm employment opportunities (Zhang, Wolz and Ding, 2020). The actual cultivation of bamboo forests is still done by individual bamboo farmers on their own land, however (personal communication, Mr. Jianping Pan, manager of Fumin Bamboo Shoot Specialized Cooperative, August 2018).

Starting in late 2018, there have been more integrated production cooperatives that manage bamboo forests for all the members. For example, the Tianlin Production Cooperatives in Anji County owns 20,000 mu of bamboo forests, with members from 156 families (Xinhua Finance, 2020). Under an integrated cooperative, bamboo farmers transfer the right to manage their land to the cooperative, letting the cooperative hire labor and jointly manage the land from multiple farmers, and farmers receive dividends. Collective management and land transformation are responses to the diminishing profit from bamboo forests. Under this collective management regime, it is possible that an individual farmer has more market power, but given the total number of bamboo farmers in the province, even production cooperatives seem to be price takers in the bamboo market.

Since fresh bamboo shoots are hard to store and transport for long distances, the majority of the fresh bamboo shoots are sold to markets in Zhejiang province, Jiangsu Province, and Shanghai. In addition, approximately 15% of the winter shoots and one third of the spring shoots are sold to local shoots processing factories (Wu et al., 2016). Consumers of bamboo shoots are from highly populated areas such as Shanghai, as well as other cites in Zhejiang and Jiangsu province including but not limited to Yongkang, Cixi, Yuyao, Dongyang, Shangyu, Fuyang, Shaoxing, Ningbo, Changzhou, Suzhou, and Hangzhou (Shen et al., 1998; Wu et al., 2016). Most of the bamboo stem are processed locally within each county to reduce transportation costs and to contribute to local economic growth (Kusters & Belcher, 2004). Consumers of bamboo stems are generally local bamboo stem processing and manufacturing factories, due to the high transportation costs and the initiatives to contribute to local economic growth (Zhang, 2003; Kusters and Belcher, 2004). Moso bamboo stem and shoots are not only produced in Zhejiang province but also in Hunan, Fujian, Jiangxi, and Sichuan provinces. Bamboo shoots, and especially

winter shoots on Zhejiang market are from all these markets, and compete for the same consumers. (People.cn, 2014).

2.5.Bamboo shoots price

Bamboo shoots prices vary day to day and are hard to predict. Bamboo shoot prices also differ for spring bamboo shoots and winter bamboo shoots. Due to difficulties of locating and harvesting underground winter bamboo shoots, as well as popular preference over more tender taste, winter bamboo shoots have higher market price than spring bamboo shoots. As long as the shoots are underground and have not emerged above ground, they are called winter shoots. Winter shoots remain dormant during the coldest winter days in January and February, and emerge above ground in March when the temperature rises. Due to their dormancy, the nutrient contents do not change by much in these two months (Su, 2012). Technically, winter shoots could still be harvested and sold on the market for a high winter shoots price until they emerge above ground and start to be called spring shoots.

In addition, spring shoots taste bitter, are no longer tender, and are no longer even considered a good source of vegetable (LeBeau Bamboo Nursery, 2015) and therefore will be unpopular on the market after they exceed 30 cm (or about 1 foot), which is after around 10 days of spring shooting (Tao et al. 2020). The maximum period for which spring shoots are traded and spring shoots prices are recorded on the wholesale market for Zhejiang province is from March 1 to June 13, which is longer than the local number of days spring shoots are on the market because it incorporates all townships in Zhejiang province, each of which has a spring shoots market period of around 60 days that occur at different times. In Shanchuan and Sian Townships, the maximum number of days for which spring shoots are traded and spring shoots prices are recorded on the wholesale market is from March 1st to April 30, which is 61 days. These are from data and interviews.

According to data from National Agricultural Products Business Information Public Service Platform operated by China's Ministry of Commerce, bamboo shoots prices are volatile in Zhejiang province. The bamboo shoot price in a representative market in Jiaxing in Zhejiang province varied from 3.06 ¥/kg to 24.75 ¥/kg in 2017. Bamboo shoot prices in Zhejiang province followed a similar pattern from 2014 to 2018, with the highest prices in the winter. Bamboo shoot prices are in the range of 2 ¥/kg to 40 ¥/kg, with highest price generally appearing in November,

and the lowest price generally appearing in May. Bamboo shoot prices tend to vary a lot within and between years. According to data from the Nanjing Administration of Agriculture and Rural Area,[3] bamboo shoot prices in China during the years 2017-2018 were in the range of 3 ¥/kg to 26 ¥/kg, with highest price appearing between December and February, and the lowest price appearing in May. According to data from the Jiaxing Vegetable Wholesale Transaction Market in Zhejiang province, one of the largest and closest wholesale markets for vegetables in Zhejiang province, the daily winter shoots price over the winter shooting season (September 1 to February 28) over the years 2016-2018 varied from 4.7 ¥/kg to 32 ¥/kg, with a mean of 16.60 ¥/kg and a standard deviation of 6.93 ¥/kg; and the daily spring shoots price over the spring shooting season (March 1 to August 31) over the years 2016-2018 varied from 0.60 ¥/kg to 20 ¥/kg, with a mean of 5.68 ¥/kg and a standard deviation of 4.08 ¥/kg. Data from 2016-2018 for Longyou Township in Zhejiang province show that bamboo shoots prices vary a lot (Yue et al., 2019).

2.6.Bamboo stem price

The bamboo stem price does not vary much over the course of a year. There is not much price volatility in bamboo stem price within a year (personal communication with Jianping Pan, director of Fumin Bamboo Shoot Specialized Cooperative, in August 2018), and there is not much price change between years during the year of our data set. This is confirmed by the production record data from Tianlin Bamboo and Shoots Production Cooperatives as price for one kilograms of stem only varies within 0.5 dollars within a year, and only for a few days. According to online data for bamboo stem price for Lechang Township in Guangdong Province, the bamboo stem price remained stable based on spot price on several days from different months during 2017-2018 (China Timber, 2022). Bamboo stem price remained stable from 2016-2018 in Longyou Township in Zhejiang province (Yue et al., 2019).

According to Wu and Cao (2016), the 2012 Moso bamboo stem price is ¥1.39/kg in Zhejiang province. Meng, Liu, and Wu (2014) find average bamboo stem price to be ¥0.79/kg.

2.7. Bamboo forest maintenance cost, harvesting costs, and planting costs

Bamboo management and harvest costs vary for different provinces. According to a recent study using randomized data from representative sampling in three provinces, the primary costs

[3] http://nyncj.nanjing.gov.cn/fww/xq/jgzs/

for managing a bamboo forest are labor costs, and an additional minor cost is fertilizer (Wu and Cao, 2016).

The average labor cost in Zhejiang province is ¥125 per worker per day. One hectare Moso bamboo is estimated to cost ¥4100 annually on labor. An increase in labor input increases the quantity harvested for both bamboo stem and bamboo shoots (Wu and Cao, 2016). Labor hours differ for timber forest and timber-shoots forest, where the former aims at bamboo stem production and the latter has two major products (Meng, Liu and Wu, 2014).

Bamboo planting costs include land finishing costs, planting labor costs, and bamboo mother plants costs, accordingly account for 39.4, 30.9 work-day per hector, and ¥15 per mother plant. These add up to a ¥14,712.5/ha one-time cost (Meng, Liu and Wu, 2014).

Maintenance costs vary in the range of 5.4 to 14.4 work-day per hectare annually, with average labor cost of ¥125/work-day in Zhejiang province. Average maintenance cost per hectare in Zhejiang province is estimated to be ¥675/ha to ¥1,800/ha annually. The difference in costs is due to age of bamboo forests. In their study, "forest formation year" is used to name the ninth year when maintenance costs decrease sharply. Intensive labor is ideal before bamboo forest formation year, and decreases sharply after forest formation year (Meng, Liu and Wu, 2014).

The bamboo shoot and bamboo stem harvest cost is determined by labor costs (Wu and Cao, 2016) as well as land specific characteristics such as the slope of forest land (Wu and Cao, 2016; Dong et al., 2015). Due to decreasing profits from bamboo forests, younger workers in rural areas have left their hometown and started to find jobs in large cities such as Hangzhou and Shanghai, leaving less labor to manage bamboo forests in rural areas of Zhejiang province; this insufficient labor supply has resulted in increasing labor costs in recent years (Jiang, 2020).

According to Mr. Jianping Pan, who is the manager of Fumin Bamboo Shoot Specialized Cooperative, bamboo harvest can be fast, one worker can harvest 1 mu (about 667 square meters) of bamboo per day. For bamboo stem, workers get paid daily with a rate of 300 yuan per day and harvest 1,250 to 2,000 kg of bamboo stem. For spring shoots, workers got paid daily, with a rate of 150 to 180 yuan per day, and can harvest 100 kg of spring shoots per day; the total harvest for each sample plot is 200-250 kg per spring shooting period. Winter shoots are more expensive and harder to find than spring shoots, and thus workers get paid for 300 yuan per day and can harvest about 15 to 20 kg per day (personal communication, Mr. Jianping Pan, manager of Fumin Bamboo Shoot Specialized Cooperative, August 2018).

Average shoots harvesting costs are estimated to be 1.9 work-day per hectare annually, which is ¥237.5/ha per year. Bamboo stem harvesting cost is 14 work-day per hectare annually, which is ¥1,750/ha per year (Meng, Liu and Wu, 2014).

Fertilizer use in bamboo forests cost 1,000 yuan per year, with an additional cost of 2,000 yuan on labor to spread fertilizer. Bamboo stem density ranges from 1,750 to 3,000 per ha for different areas. Increasing fertilizer usage significantly boosts bamboo shoots yields, but has little effect on bamboo stem output (Wu and Cao, 2016).

3. Insights from Interviews of Moso Bamboo Farmers in China

We interviewed 24 bamboo farmers in Zhejiang, China in December 2023 to better understand their bamboo stem and shoots harvesting behaviors and financial status. Interviews were conducted in Chinese. We interviewed bamboo farmers from 3 different counties in Zhejiang province: Anji County (where Shanchuan Township is located), Changxing County (where Sian Township is located), and Shengzhou County. We did not provide any monetary award or compensation to the interviews, as a possible concern that a monetary award for participants will attract participants in most need of cash, which may lead our sample to possibly be skewed towards farmers who are liquidity constrained, and may bias responses in favor of liquidity constraints as a mechanism. We provided snacks and tea for bamboo farmers during the interviews as an incentive to attract participants.

Figure 1 plots the distribution of bamboo farmers we interviewed by the number of years they have been managing bamboo forests. Most of the bamboo farmers we interviewed have been managing bamboo forests for over 20 years.

Figure 2 plots the proportion of annual income from bamboo harvests. For most of the bamboo farmers we interviewed, profits from bamboo harvests constitute 30% or less of their annual income.

The most often cited factors that affect the timing of bamboo shoots harvests include: harvesting when there are shoots in the ground, the risk of shoots rotting in the ground, labor costs being covered by harvest revenue, market price, and when the shoots are large (Figure 3).

As seen in Figure 4, the most cited reason among bamboo farmers we interviewed for harvesting bamboo shoots earlier during winter shooting is the probability that shoots might not

survive. Other reasons include facilitating later winter shoots development and liquidity constraints.

Many bamboo farmers we interviewed tend to have the most cash on hand during bamboo harvests (Figure 5), and the least amount of cash on hand when there are no shoots or stems to be harvested (Figure 6). Many bamboo farmers we interviewed have not run short on money; among those who have run short on money, coping strategies include harvesting bamboo shoots or stems; finding other opportunities to make money, such as a part-time job using the bamboo forest to raise poultry or grow herbs; borrowing money from a bank, trust, friends, or family; and managing in a less expensive way such as by applying less fertilizer (Figure 7). Common strategies bamboo farmers have undertaken to avoid running short on cash include finding a part-time job, finding other opportunities to earn money, harvesting bamboo shoots or stems, and planning ahead (Figure 8).

4. Discussion and Conclusion

Moso bamboo is the single most important bamboo species in China, accounting for 74% of China's bamboo forest area, as well as the third most important source of timber in China. Both bamboo shoots and bamboo stems are harvested as valuable products: bamboo shoots are a traditional food source, and bamboo stems are used as timber for paper making, flooring, and construction.

Various management styles have been found in bamboo forests in Asia, and the decisions of bamboo farmers can be complex and hard to understand (Yen, 2015). The bamboo stem harvests and bamboo shoot harvests decisions made by Chinese bamboo farmers may be unsustainable, leading to profit loss and a deterioration of the bamboo forest resource. The bamboo stem price has decreased significantly in recent years, and some bamboo plants have been left unharvested when matured due to high harvest cost. In contrast, winter shoots have sometimes been over-harvested for high profit, leaving too few shoots for future bamboo forest development.

Wu et al. (2025a) develop a nested stochastic dynamic bioeconomic model of optimal forest management under uncertainty for interdependent products, and find that actual bamboo stem and bamboo shoot harvests in Zhejiang province come close to approximating the optimal harvesting strategy, though some differences remain. First, given relatively low bamboo stem prices, farmers might do even better by waiting even more years before harvesting bamboo stem.

Second, for the plots in our data set, even when there are few shoots, and even with the possibility of winter shoots death and high winter shoots prices, the frequency and/or quantity of winter shoots harvest might be higher than optimal, and contrary to the traditional bamboo management guidance to avoid harvesting too many winter shoots before spring shoots emerge, in order to foster a new bamboo forest (Forestry Department of Hunan Province, 2008). These results are consistent with anecdotal evidence that winter shoots have sometimes been over-harvested for high profit, leaving too few shoots for future bamboo forest development. Wu et al. (2025a) also estimate a dynamic structural econometric model and results suggest three possible sources of differences between actual and optimal harvests: a higher perceived winter shoots growth rate, more convex costs to shoots harvest, and risk aversion. Each of these three channels would explain why actual winter shoots harvests in the data are higher and more frequent than what their model suggests is optimal.

The most cited reason among bamboo farmers we interviewed for harvesting bamboo shoots earlier during winter shooting is the probability that shoots might not survive. Other reasons include facilitating later winter shoots development and liquidity constraints. Moreover, among bamboo farmers we interviewed, harvesting bamboo shoots and bamboo stems is one common strategy to cope with liquidity constraints.

References

Amidon, E.L., and G.S. Akin. (1968). Dynamic programming to determine optimum levels of growing stock. Forest Science, 14(3), 287-291.

Arimizu, T. (1958). Regulation of the cut by dynamic programming. Journal of the Operations Research Society of Japan, 1(4), 175-182.

Bare, B.B., and T.R. Waggener. (1980). Forest land values and return on investment. Forest Science, 26(1), 91-96.

Berck, P. (1981). Optimal management of renewable resources with growing demand and stock externalities. Journal of Environmental Economics and Management, 8(2), 105-117.

Bowes, M.D. (1983). Economic foundations of public forestland management. Resources for the Future.

Brodie, J.D., and C. Kao. (1979). Optimizing thinning in Douglas-fir with three-descriptor dynamic programming to account for accelerated diameter growth. Forest Science, 25(4), 665-672.

Brodie, J.D., D.M. Adams, and C. Kao. (1978). Analysis of economic impacts on thinning and rotation for Douglas-fir, using dynamic programming. Forest Science, 24(4), 513-522.

Buongiorno, J., and J.K. Gilless. (2003). Decision Methods for Forest Resource Management. Academic Press, San Diego.

Bystriakova, N., V. Kapos, I. Lysenko, and C.M.A Stapleton. (2003). Distribution and conservation status of forest bamboo biodiversity in the Asia-Pacific Region. Biodiversity & Conservation, 12(9), 1833-1841.

Calish, S., R.D. Fight, and D.E. Teeguarden. (1978). How do nontimber values affect Douglas-fir rotations?. Journal of Forestry, 76(4), 217-221.

Chang, S. (1982). An economic analysis of forest taxation's impact on optimal rotation age. Land Economics, 58(3), 310-323.

Chang, S.J. (1981). Determination of the optimal growing stock and cutting cycle for an uneven-aged stand. Forest Science, 27(4), 739-744.

Chang, S.J. (1983). Rotation age, management intensity, and the economic factors of timber production: Do changes in stumpage price, interest rate, regeneration cost, and forest taxation matter? Forest Science, 29(2), 267-277.

Chen, A., and S. Scott. (2014). Rural development strategies and government roles in the development of farmers' cooperatives in China. Journal of Agriculture, Food Systems, and Community Development, 4(4), 35-55.

Chen, C.M., D.W. Rose, and R.A. Leary. (1980). Derivation of optimal stand density over time—a discrete stage, continuous state dynamic programming solution. Forest Science, 26(2), 217-227.

China Forestry and Grassland Administration. (2018). Forest Resources in China.

China Timber. (2022). Bamboo Stem Price Trend. China Timber. Retrieved 2 November 2022. URL: http://www.chinatimber.org/price/price.asp?wood=8&pageno=4

Deegen, P., M. Hostettler, and G.A. Navarro. (2011). The Faustmann model as a model for a forestry of prices. European Journal of Forest Research, 130(3), 353-368.

Démurger, S., Y. Hou, and W. Yang. (2009). Forest management policies and resource balance in China: An assessment of the current situation. Journal of Environment and Development, 18(1), 17-41.

Dong, D., Y. Tong, X. Yi., C. Zhang, and M. Gu. (2015). Harvesting cost and economics efficiency analysis of bamboo forests in various slope hill lands. Journal of Bamboo Research, 34(4), 23-27. [in Chinese]

Fang, J.Q., and Z. Xie. (1994). Deforestation in preindustrial China: The Loess Plateau region as an example. Chemosphere, 29(5), 983-999.

Faustmann, M. (1849). Calculation of the value which forest land and immature stands possess for forestry. General Journal of Forestry and Hunting. [in German]

Fekedulegn, D., M.P. Mac Siurtain, and J.J. Colbert. (1999). Parameter estimation of nonlinear growth models in forestry. Silva Fennica, 33 (4), 653.

Forestry Department of Hunan Province. (2008). Moso Bamboo Cultivation Techniques. 25 April 2008.

Fu, J. (2001). Chinese Moso bamboo: its importance. Bamboo, 22(5), 5-7.

Gregersen, H.M. (1975). Effect of inflation on evaluation of forestry investments. Journal of Forestry, 73(9), 570-572.

Hadley, C.L., C.A. Wolf, and S.B. Harsh. (2006). Dairy cattle culling patterns, explanations, and implications. Journal of Dairy Science, 89(6), 2286-2296.

Haight, R.G. (1985). A comparison of dynamic and static economic models of uneven-aged stand management. Forest Science 31(4), 957-974.

Hall, D.O. (1983). Financial maturity for even-aged and all-aged stands. Forest Science, 29(4), 833-836.

Hardie, I.W., J.N. Daberkow, and K.E. McConnell. (1984). A timber harvesting model with variable rotation lengths. Forest Science, 30(2), 511-523.

Hartman, R. (1976). The harvesting decision when a standing forest has value. Economic Inquiry, 14(1), 52-58.

International Bamboo and Rattan Organisation [INBAR]. (2012). China Bamboo Industry Plans at National and Provincial Levels. INBAR. Accessed 15 February 2022. URL: https://www.inbar.int/resources/inbar_publications/china-bamboo-industry-plans-at-national-and-provincial-levels/

Jackson, D. H. (1980). The Microeconomics of the Timber Industry. Westview Press.

Jiang, Y. (2020). How to achieve one-on-one efficient reduction of poverty. JYB.cn, 25 May 2020. Retrieved February 18, 2022. URL: http://www.jyb.cn/rmtzgjyb/202005/t20200525_330371.html [in Chinese]

Jiang, Z. (2007). Bamboo and Rattan in the World. Beijing: China Forestry Pub. House.

Kant, S., and J.R.R. Alavalapati. (2014). Handbook of Forest Resource Economics. Abingdon: Routledge.

Katsigris, E., G.Q. Bull, A. White, C. Barr, K. Barney, Y. Bun, F. Kahrl, T. King, A. Lankin, A. Lebedev, P. Shearman, A. Sheingauz, Y. Su, and H. Weyerhaeuser. (2004). The China forest products trade: Overview of Asia-Pacific supplying countries, impacts and implications. International Forestry Review, 6(3/4), 237-253.

Kilkki, P., and U. Väisänen. (1969). Determination of the optimum cutting policy for the forest stand by means of dynamic programming. Acta Forestalia Fennica, 102.

Klemperer, W.D. (1979). Inflation and present value of timber income after taxes. Journal of Forestry, 77(2), 94-96.

Kusters, K., and B. Belcher. (2004). Forest Products, Livelihoods and Conservation: Case studies of non-timber forest product systems. Volume 1 - Asia. Center for International Forestry Research (CIFOR).

LeBeau Bamboo Nursery. (2015). Bamboo as a Vegetable—Harvesting Edible Bamboo Shoots. 15 June 2014. Retrieved April 10, 2021. URL: https://lebeaubamboo.com/article-bamboo-vegetable-harvesting-bamboo-shoots.php

Li, C., G.M. Zhou, Y.J. Shi, Y.F. Zhou, X.J. Xu, Y.P. Zhang, Y.Q. Fan, and Z.M. Shen. (2016). Effects of old bamboo forests and relevant management measures on growth of new bamboo forests. Acta Ecologica Sinica, 36(8), 2243-2254. [in Chinese]

Matthews, R. (2012). The economic and employment benefits of forests. Eco-Business, 7 March 2012.

McConnell, K.E., J.N. Daberkow, and I.W. Hardie. (1983). Planning timber production with evolving prices and costs. Land Economics, 59(3), 292-299.

Meng, H., Q. Liu, and W. Wu. (2014). Study on the cost-benefit and carbon sequestration capacities of Phyllostachys edulis plantations under different types of management. Journal of Zhejiang A&F University, 31(6): 959-964. [in Chinese]

Nath, A.J., G. Das, and A.K. Das. (2009). Above ground standing biomass and carbon storage in village bamboos in North East India. Biomass and Bioenergy, 33(9), 1188-1196.

National Agricultural Products Business Information Public Service Platform. (2018). People's Republic of China Ministry of Commerce.. Retrieved from http://nc.mofcom.gov.cn/ [in Chinese].

Nautiyal, J.C., and J.S. Williams. (1990). Response of optimal stand rotation and management intensity to one-time changes in stumpage price, management cost, and discount rate. Forest Science, 36(2), 212-223.

Newman, D.H., C.B. Gilbert, and W.F. Hyde. (1985). The optimal forest rotation with evolving prices. Land Economics, 61(4), 347-353.

Newman, D.H. (1988). The optimal forest rotation: A discussion and annotated bibliography. Gen. Tech. Rep. SE-48. Asheville, NC: US Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.

Nguyen, D. (1979). Environmental services and the optimum rotation problem in forest management Journal of Environmental Management, 8(2), 127-136

Ollikainen, M. (1991). The effect of nontimber taxes on the harvest timing—the case of private nonindustrial forest owners: A note. Forest Science, 37(1), 356-363.

Pearse, P.H. (1967). The optimum forest rotation. The Forestry Chronicle, 43(2), 178-195.

People.cn. (2014). One hundred tons of daily winter shoot consumption in Hangzhou: Why winter shoots are more tender and valuable? (2014). People.cn, 26 November 2014. Retrieved February 16, 2022. URL http://travel.people.com.cn/n/2014/1126/c41570-26095502.html [in Chinese]

Pérez, M.R., M. Zhong, B. Belcher, C. Xie, M. Fu, J. Xie. (1999). The role of bamboo plantations in rural development: The case of Anji County, Zhejiang, China. World Development, 27(1), 101-114.

Richards, F. (1959). A flexible growth function for empirical use. Journal of Experimental Botany, 10(2), 290-301.

Rideout, D.B. (1982). Micro-Economic Properties of Four Local Forest Tax Methods. Doctoral dissertation, University of Washington.

Riitters, K.H., J.D. Brodie, and D.W. Hann. (1982). Dynamic programming for optimization of timber production and grazing in ponderosa pine. Forest Science, 28(3), 517-526.

Rosen, S., K.M. Murphy, and J.A. Scheinkman. (1994). Journal of Political Economy, 102(3), 468-492

Samuelson, P.A. (1976). Economics of forestry in an evolving society. Economic Inquiry, 14(4), 466-492.

Scurlock, J.M.O., D.C. Dayton, and B. Hames. (2000). Bamboo: an overlooked biomass resource? Biomass and Bioenergy, 19(4), 229-244.

SFA. (2014b). Report of forest resources in China (2009–2013). China Forestry Press, Beijing, p 86.

Shen, Y., Y. Cheng, X. Xu, X. Cai, B. Zhang. (1998). Analysis prediction of market supply and demand for bamboo shoot products. Journal of Zhejiang A&F University, 15(4), 333-339. [in Chinese]

Shi, Y., E. Liu, G. Zhou, Z. Shen, and S. Yu. (2013). Bamboo shoot growth model based on the stochastic process and its application. Scientia Silvae Sinicae, 49(9), 89-93. [in Chinese]

Strang, W.J. (1983). On the optimal forest harvesting decision. Economic Inquiry, 21(4), 576-583.

Su, W. (2012). Fertilization theory and practice for Phyllostachys edulis stand based on growth and nutrient accumulation rules. (doctoral dissertation). Chinese Academy of Forestry, Beijing, China.

Tao, G.-Y., M. Ramakrishnan, K.K. Vinod, K. Yrjala, V. Satheesh, J. Cho, Y. Fu, and M. Zhou. (2020). Multi-omics analysis of cellular pathways involved in different rapid growth stages of moso bamboo. Tree Physiology, 40 (11), 1487-1508.

Tonsor, G.T. (2011). Evaluating cattle cycles: Changes over time and implications. Kansas State University Department of Agricultural Economics Publication AM-GTT-2011.4. URL: https://www.agmanager.info/evaluating-cattle-cycles-changes-over-time-and-implications

Tyler, A.L., D.C. MacMillan, and J. Dutch. (1996). Models to predict the General Yield Class of Douglas fir, Japanese larch and Scots pine on better quality land in Scotland. Forestry: An International Journal of Forest Research, 69(1), 13-24.

U.S. Department of Agriculture [USDA]. (2025). Cattle & Beef - Sector at a Glance. Economic Research Service. Accessed 1 July 2025. URL: https://www.ers.usda.gov/topics/animal-products/cattle-beef/sector-at-a-glance

Wang, S., G.C. Van Kooten, and B. Wilson, B. (2004). Mosaic of reform: Forest policy in post-1978 China. Forest Policy and Economics, 6(1), 71-83.

Wei, Q., C. Jiao, Y. Ding, S. Gao, L. Guo, M. Chen, P. Hu, S. Xia, G. Ren, and Z. Fei. (2018). Cellular and molecular characterizations of a slow-growth variant provide insights into the fast growth of bamboo. Tree Physiology, 38, 641-654.

Wicksell, K. ([1901] 1934). Lectures on Political Economy. Trans. E. Classen. New York: Macmillan Company.

Wu, T., D.R. Just, C.-Y.C. Lin Lawell, J. Zhao, Z. Fei, A. Ortiz-Bobea, and Q. Wei. (2024). Optimal forest management under uncertainty: A framework for stochastic dynamic bioeconomic modeling. International Business Analytics Conference Proceedings, 1 (1), 56-61.

Wu, T., D.R. Just, C.-Y.C. Lin Lawell, A. Ortiz-Bobea, and J. Zhao. (2025a). Optimal forest management for interdependent products: A nested stochastic dynamic bioeconomic model and application to bamboo. Working paper, Cornell University.

Wu, T., D.R. Just, C.-Y.C. Lin Lawell, A. Ortiz-Bobea, J. Zhao, Z. Fei, and Q. Wei. (2025b). The bamboo cycle. Working paper, Cornell University.

Wu, W., and X. Cao. (2016) Study on the relationship between input, output and economic benefit of Moso bamboo plantation. Journal of Nanjing Forestry University (Natural Sciences Edition), 40(3), 108-114. [in Chinese]

Wu, B., H. Hu, X. Lin, S. Huang, J. Lai, and W. Li. (2016). A study of bamboo shoot market in Longyou County, Zhejiang. World Bamboo and Rattan, 14(6). [in Chinese]

Xinhua Finance. (2020). Guard the mountain, follows the fortune: Green Insurance in Anji Zhejiang. Xinhua Finance, 28 April 2020. Retrieved February 17, 2022. URL: http://greenfinance.xinhua08.com/a/20200428/1933450.shtml [in Chinese]

Yen, T.-M. (2015). Comparing aboveground structure and aboveground carbon storage of an age series of Moso bamboo forests subjected to different management strategies. Journal of Forest Research, 20(1), 1-8.

Yen, T.-M., and J.-S. Lee. (2011). Comparing aboveground carbon sequestration between moso bamboo (Phyllostachys heterocycla) and China fir (Cunninghamia lanceolata) forests based on the allometric model. Forest Ecology and Management, 261(6), 995-1002.

Yousefpour, R., and M. Hanewinkel. (2009). Modelling of forest conversion planning with an adaptive simulation-optimization approach and simultaneous consideration of the values of timber, carbon and biodiversity. Ecological Economics, 68(6), 1711-1722.

Yue, J., B. Wu, X. Lin, H. Hu, and J. Lai. (2019) Research on price variation of Phyllostachys edulis culm and shoot in Longyou County, Zhejiang Province. World Bamboo and Ratten, 17(1), 22-27. [in Chinese]

Zhang, C., and X. Ding. (1997). Studies on yield of Phyllostachys Heterocycla var. Pubescens stands. Journal of Bamboo Research, 16(3), 31-36. [in Chinese]

Zhang, H., S. Zhuang, B. Sun, H. Ji, C. Li, and S. Zhou. (2014). Estimation of biomass and carbon storage of moso bamboo (*Phyllostachys pubescens* Mazel ex Houz.) in southern China using a diameter–age bivariate distribution model. Forestry, 87(5), 674–682.

Zhang, Q.-S. (2003). Attaching importance to science and innovation in the processing and utilization of bamboo timber in China. Journal of Zhejiang A&F University, 20(1), 1-4.

Zhang, S., A. Wolz, and Y. Ding. (2020). Is there a role for agricultural production cooperatives in agricultural development?: Evidence from China. Outlook on Agriculture, 49(3), 256-263.

Zhu, Z. (2001). Sustainable development of the bamboo and rattan sectors in tropical China. China Forestry Publishing House.

Zhuang, S., H. Ji, H. Zhang, and B. Sun. (2015). Carbon storage estimation of Moso bamboo (Phyllostachys pubescens) forest stands in Fujian, China. Tropical Ecology, 56(3), 383-391.

Figure 1. Bamboo Farmer Experience

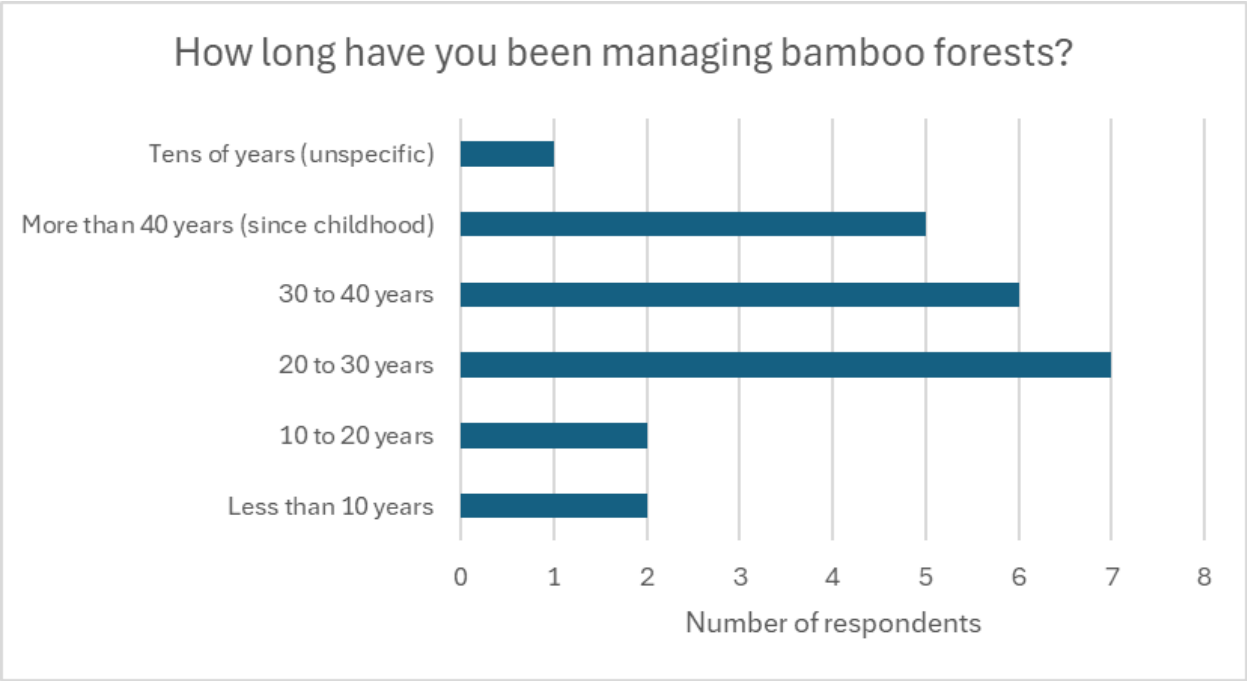

Figure 2. Proportion of Annual Income from Bamboo Harvest

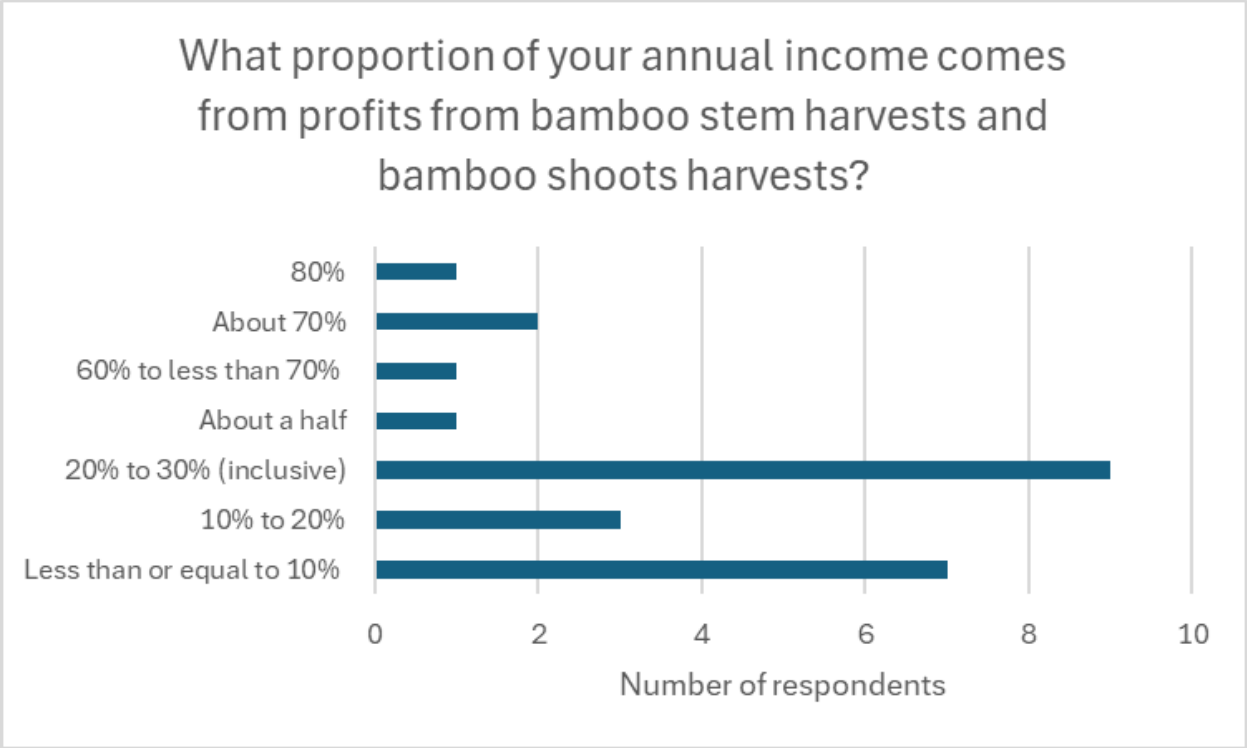

Figure 3. Factors Affecting Bamboo Shoots Harvest Timing

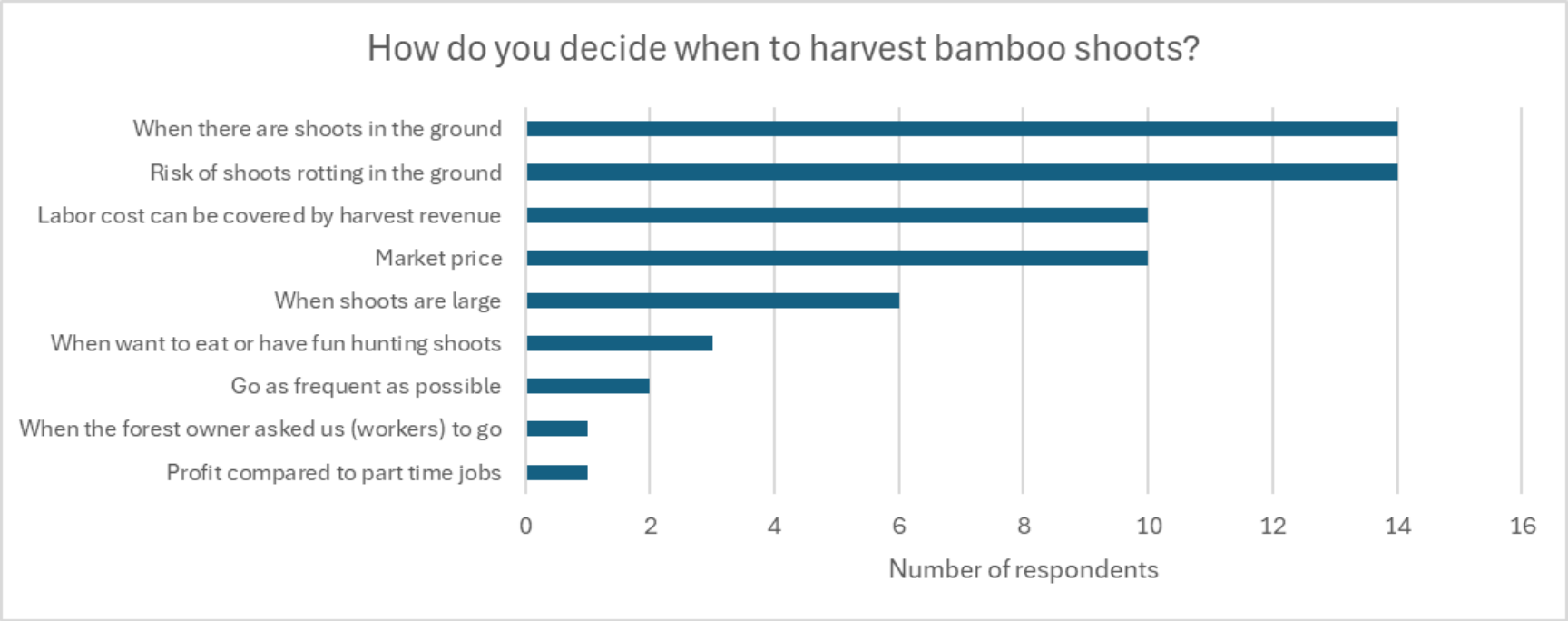

Figure 4. Reasons for Harvesting Bamboo Shoots Earlier During Winter Shooting

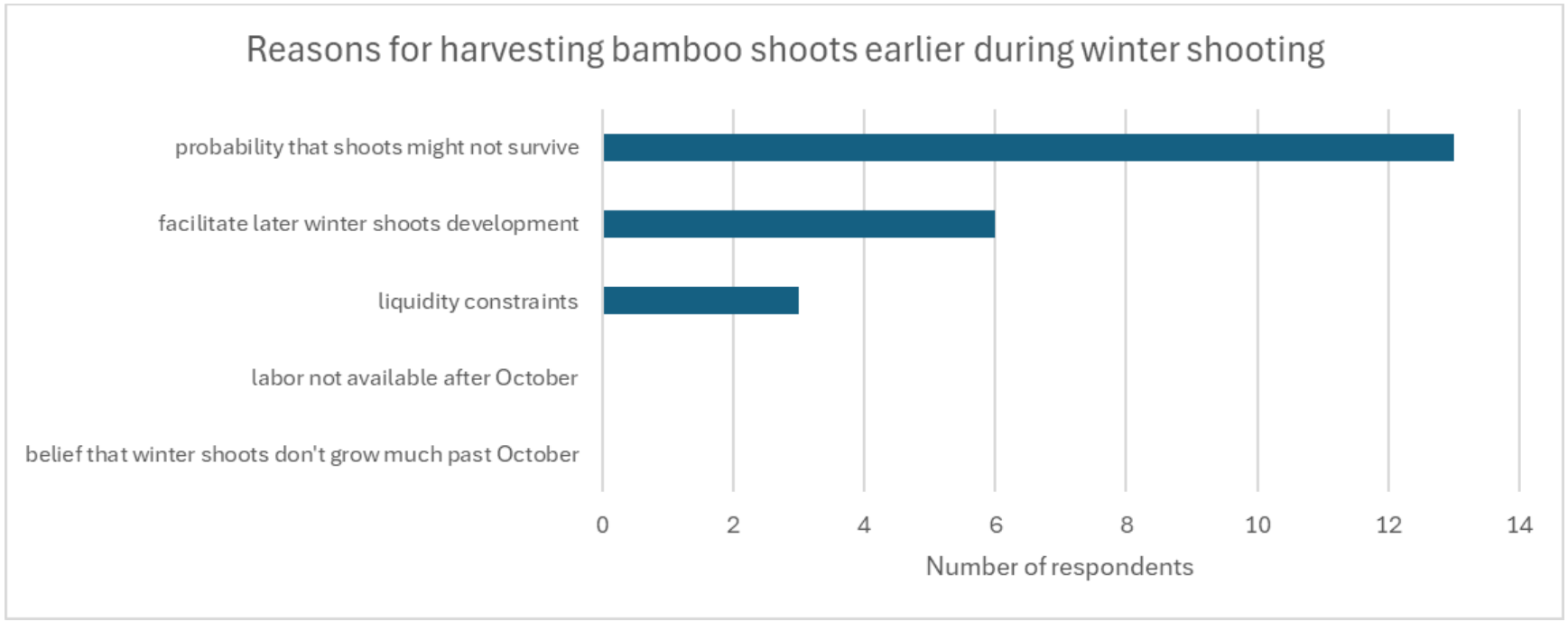

Figure 5. When bamboo farmers tend to have the most cash on hand

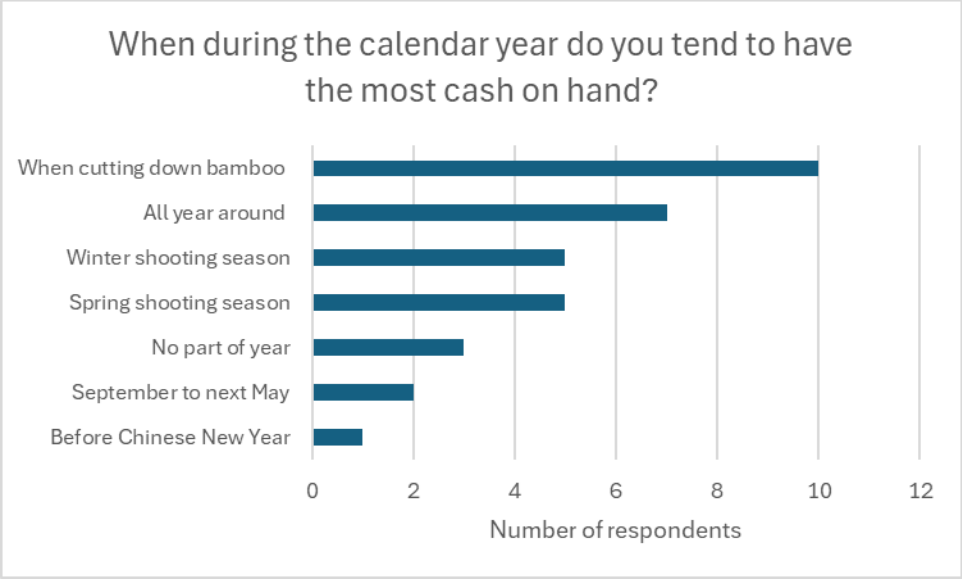

Figure 6. When Bamboo Farmers Tend to Have the Least Cash on Hand

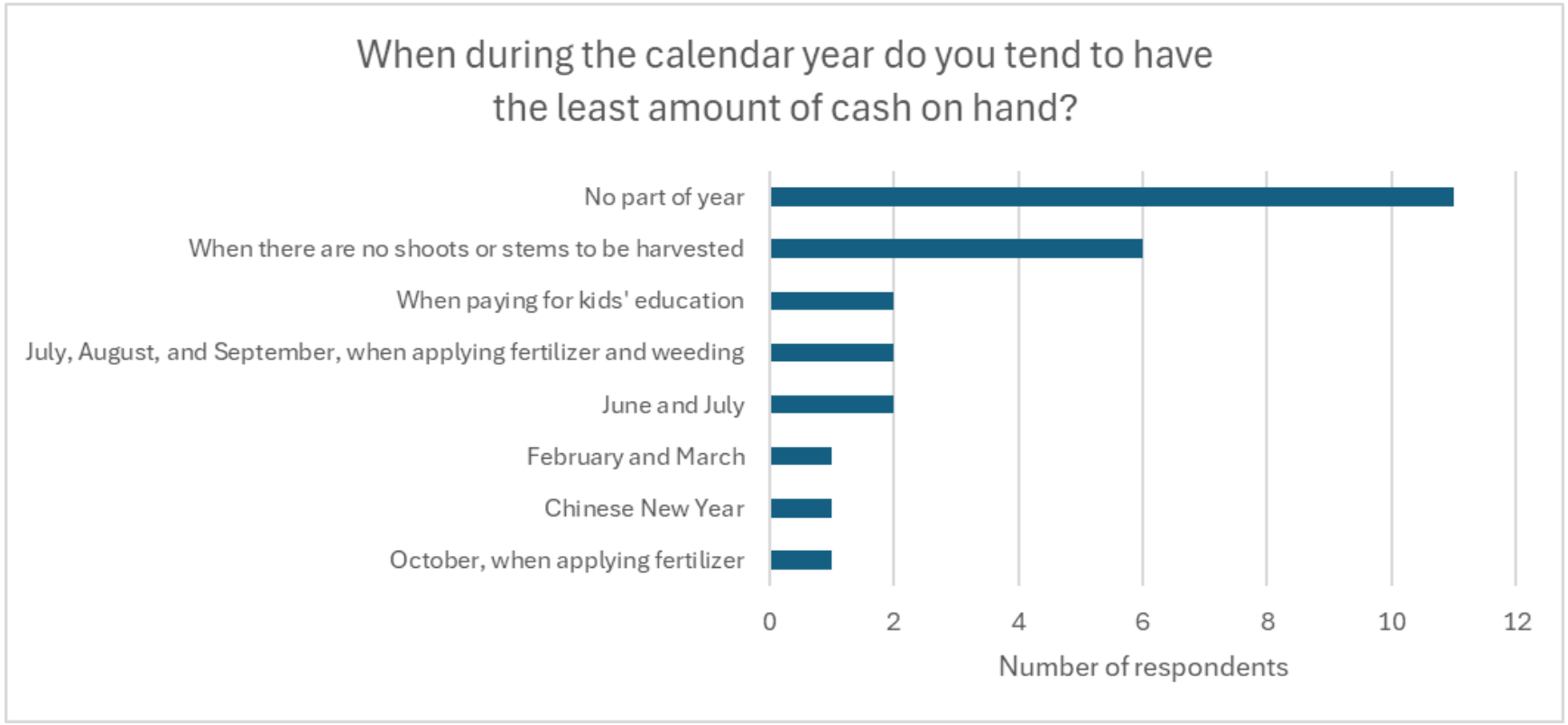

Figure 7. What Bamboo Farmers Do When They Run Short on Money

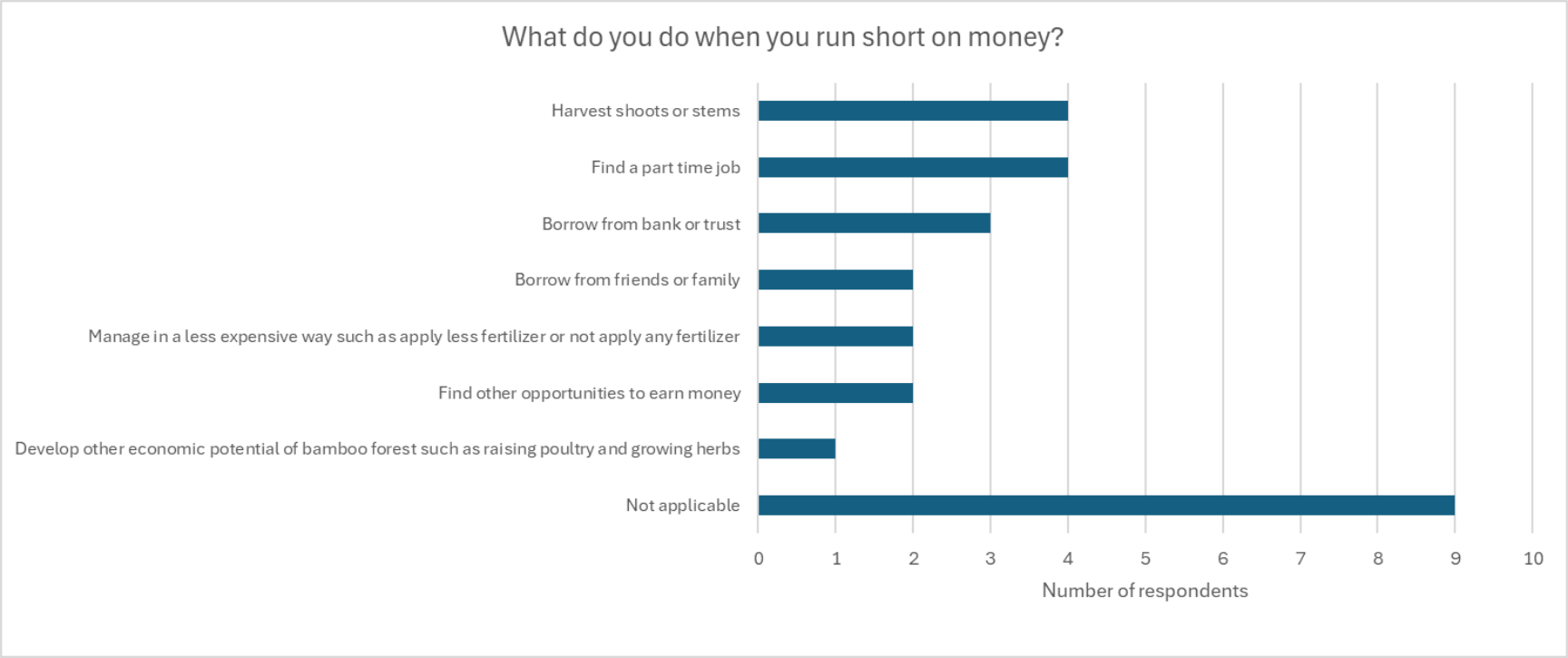

Figure 8. What Bamboo Farmers Do to Avoid Running Short on Cash