The Bamboo Cycle[1,2]

Tong Wu, Jennifer E. Ifft,
David R. Just, C.-Y. Cynthia Lin Lawell, Ariel Ortiz-Bobea,
Jiancheng Zhao, Zhangjun Fei, Qiang Wei

Abstract

We develop the notion of a bamboo cycle, analogous to the notion of a cattle cycle. The management of a bamboo forest is similar to the management of cattle; and the dynamics and interdependence of bamboo forest products share characteristics with the dynamics and interdependence of cows and calves. Just as the cattle cycle provides valuable insights into the cattle industry and helps guide predictions about the future, the bamboo cycle provides insight into patterns, relationships, and the possibly periodic and cyclic nature of bamboo forest resources, stocks, and harvest decisions, and helps guide the sustainable management of bamboo forests.

Keywords: bamboo, forest management, cattle cycle, uncertainty, interdependent products
***JEL* codes:** Q23, Q12, L73
This draft: November 2025

---

[1] Wu (corresponding author): Natural Resources Institute Finland (Luke); tong.wu@luke.fi. Ifft: Kansas State University; jifft@ksu.edu. Just: Cornell University; drj3@cornell.edu. Lin Lawell: Cornell University; clinlawell@cornell.edu. Ortiz-Bobea: Cornell University; ao332@cornell.edu. Zhao: Zhejiang Academy of Forestry; jiancheng68@163.com. Fei: Boyce Thompson Institute and Cornell University; zf25@cornell.edu. Wei: Nanjing Forestry University; weiqiang@njfu.edu.cn.

[2] We thank Qin Li, Lina Liu, Jianping Pan, and Boqing Yuan for helping us with the data collection; for providing us information about bamboo management; and for helping to host our visits to the Zhejiang Provincial Key Laboratory of Bamboo of Zhejiang Provincial Academy of Forestry, the Anji Forestry Technology Promotion Center, the Fumin Bamboo Shoot Specialized Cooperative, and the Tianlin Bamboo Shoot Specialized Cooperative, respectively. We thank Jianyang Lin, the Party Secretary for Xikou Forest Farm in Longyou County, for his exceptional support and organization for our interviews and short trips to the trade corporation in Longyou County. We thank Ryan Abman, H. Jo Albers, Jeff Arnold, Trevor Dean Arnold, Joe Balagtas, Levon Barseghyan, Rachid Belhachemi. Susanna Berkouwer, Léa Bou Sleiman, Jacob Bradt, Daniel Brent, Mike Buffo, Marshall Burke, Jonah Busch, Virginia Callison, Luming Chen, Lauren Chenarides, Sahan Dissanayake, Ida Djenontin, Victor Simoes Dornelas, Jackson Dorsey, Molly Doruska, Luc Esprabens, Zhangjun Fei, Paul Ferraro, Scott Francisco, Stephie Fried, Teevrat Garg, Todd Gerarden, Dalia Ghanem, Matthew Gibson, Tengda Gong, Gautam Gowrisankaran, Gerrit Graper, Logan Hamilton, Nils Haveresch, Yurou He, Janne Helin, Ted Helvoigt, Danae Hernández-Cortés, Alan Hinds, Jacob Holifield, Jerzy Jaromczyk, Akshaya Jha, Valerie Karplus, Aysegul Kilinc, Jim Kiniry, Cathy Kling, Samuel Kortum, Elena Krasovskaia, Yusuke Kuwayama, Katherine Lacy, Ashley Langer, Jim Lassoie, David R. Lee, Heikki Lehtonen, Arik Levinson, David Lewis, Dingyi Li, Shanjun Li, Mengwei Lin, Jules Linden, Jussi Lintunen, Tianzi Liu, Clark Lundberg, Erin Mansur, Antonia Marcheva, Shana McDermott, Brandon McFadden, Michael Meneses, Carlos Muñoz Brenes, Anjali Narang, Ishan Nath, Matías Navarro Sudy, Harry Nelson, José Nuño, Frederick Nyanzu, Anthony Ponce, David Popp, Linda Powell, Jeisson Prieto, Yu Qin, Carson Reeling, Brigitte Roth Tran, Ivan Rudik, Seth Sanders, Michelle Segovia, Jonathan Scott, Chris Severen, Jeff Shrader, Shuyang Si, Peter Smallidge, Aaron Smith, Charlie Smith, Christophe Spaenjers, Robert Stavins, Jayen Tan, Vaios Triantafyllou, Nick Tsivanidis, Calum Turvey, Wayne Walker, David Weinstein, Cade White, Matthew Wibbenmeyer, Peter Woodbury, Weiguang Wu, Tianming Yen, Shuo Yu, Terry Zhang, Hongyu Zhao, and Hui Zhou for detailed and helpful comments. We also benefited from comments from seminar participants at Cornell University, Natural Resources Institute Finland (Luke), and University of International Business and Economics (UIBE); and conference participants at the Western Forest Economists (WFE) Annual Meeting; the Northeastern Agricultural and Resource Economics Association (NAREA) Annual Meeting; an Association of Environmental and Resource Economists (AERE) session at the Western Economic Association International (WEAI) Annual Conference; the Agricultural and Applied Economics Association (AAEA) Annual Meeting; the European Association of Environmental and Resource Economists (EAERE) Annual Conference; the University of Michigan conference on Forests & Livelihoods: Assessment, Research, and Engagement (FLARE); and the International Business Analytics Conference (IBAC). This research was supported by Cornell Center for Social Sciences Cloud Computing Solutions, and was conducted with support from the Cornell University Center for Advanced Computing. We received funding for our research from the USDA National Institute of Food and Agriculture (NIFA); Cornell TREESPEAR Research Grants; Cornell DEEP-GREEN-RADAR Research Grants; and Cornell University Graduate School Conference Grants. Our IRB protocol (Protocol Number: IRB0148123) was granted exemption from IRB review according to Cornell IRB policy and under the Department of Health and Human Services Code of Federal Regulations 45CFR46.104(d). Just, Lin Lawell, and Ortiz-Bobea are Faculty Fellows at the Cornell Atkinson Center for Sustainability. All errors are our own.

1. Introduction

Bamboo is a very fast growing, renewable, versatile, and easy-to-grow resource touted for its environmental and sustainability benefits (Econation, 2025; Lewis Bamboo, 2025; Guadua Bamboo, 2025). Bamboo forests generate two interdependent products: bamboo shoots and bamboo stems. Bamboo shoots grow annually from underground bamboo stem structures, and only grow within a year (Wu et al., 2025a). Bamboo stems continue to grow each year until age 4-5 years, when they reach their maximum biomass (Zhang et al., 2014; Zhuang et al., 2015). The harvesting of bamboo stems entails cutting down the bamboo plant, while the harvesting of bamboo shoots does not (Wu et al., 2025a). Bamboo shoots are a traditional food source, and bamboo stems are used as timber for paper making, flooring, and construction (Fu, 2001).

In this paper, we develop the notion of a bamboo cycle analogous to the agricultural economics notion of a cattle cycle, which is a period of time that describes cattle producers' decisions to grow and decrease the size of their herds (USDA, 2025; Tonsor, 2011). The cattle cycle is essentially an agricultural representation of a dynamic process that illustrates how interdependent products can affect each other, given uncertainty in prices and climate change. The management of a bamboo forest is similar to the management of cattle; and the dynamics and interdependence of bamboo forest products share characteristics with the dynamics and interdependence of cows and calves. Like cattle producers, bamboo farmers face multiple sources of uncertainty; for bamboo farmers, the sources of uncertainty include precipitation, prices, and the possibility of bamboo shoots death. Just as in cattle production, when there is both uncertainty and interdependent forest products, the interaction between these two phenomena leads to a complicated set of trade-offs (Wu et al., 2025a).

The bamboo cycle is a coupled system of ecological growth and market response under uncertainty. It highlights how shoot and stem dynamics feed into long-run forest health, and how economic and environmental uncertainty influences decisions at each stage. Just as the cattle cycle provides valuable insights into the cattle industry and helps guide predictions about the future (Schulz, 2025), the bamboo cycle provides insight into patterns, relationships, and the possibly periodic and cyclic nature of bamboo forest resources, stocks, and harvest decisions, and helps guide the sustainable management of bamboo forests.

We contribute to, draw parallels from, and integrate the erstwhile separate literatures on cattle management and cattle cycles (Foster and Burt, 1992; Rosen, Murphy and Scheinkman, 1994; Marsh, 1999; Hadley, Wolf and Harsh, 2006; Crespi, Xia and Jones, 2010; Tonsor, 2011; Blank, Saitone and Sexton, 2016; McKendree, Saitone and Schaefer, 2020), and on forest management (Faustmann, 1849; Wicksell, [1901] 1934; Pearse, 1967; Samuelson, 1976; Hartman, 1976; Nguyen, 1979; Chen, Rose and Leary, 1980; Jackson, 1980; Bare and Waggener, 1980; Berck, 1981; Riitters, Brodie and Hann, 1982; Chang, 1983; McConnell, Daberkow and Hardie, 1983; Hall, 1983; Strang, 1983; Reed, 1984; Newman, Gilbert and Hyde, 1985; Krutilla and Bowes, 1989; Nautiyal and Williams, 1990; Buongiorno, and Gilless, 2003; Yousefpour and Hanewinkel, 2009; Deegen, Hostettler and Navarro, 2011; Sims, 2013; Kant and Alavalapati, 2014; Oldekop et al., 2019; Souza-Rodrigues, 2019; Araujo, Costa and Sant'Anna, 2020; Lintunen, Rautiainen and Uusivuori, 2022; Balboni et al., 2023; Wu et al., 2025a; Wang, Amacher and Xu, 2025; Wu et al., 2025b). Wu et al. (2024) provide a recent review of the literature on optimal forest management.

The balance of our paper proceeds as follows. Section 2 discusses the bioeconomics of bamboo. We describe the concept of a bamboo cycle and draw parallels to the cattle cycle in Section 3. We the discuss implications of these cycles for producers and policy in Section 4. Section 5 concludes.

2. Bioeconomics of Bamboo

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), and is touted for its environmental and sustainability benefits (Econation, 2025; Lewis Bamboo, 2025; Guadua Bamboo, 2025).

China has the world's most copious bamboo forest resources, with more than 500 bamboo species in 39 genera covering 6.01 million hectares of bamboo forest. 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. Moso bamboo distributes mostly in subtropical provinces including Fujian, Hunan, Zhejiang, and Jiangxi. Temperature, precipitation, and soil conditions affect bamboo shoot growth. The mean annual temperature in areas 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 800 mm (31.5 inches) and soil fertile loam deeper than 60 cm (23.5 inches) with pH of 4.5 to 7.0 are ideal for Moso bamboo growth (Fu, 2001).

Bamboo shoots grow annually from a bamboo plant's rhizomes, which are underground bamboo stem structures. A bamboo growth year begins each 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 at the beginning of the bamboo growth year, as well as the precipitation in July and August of the previous bamboo growth year (Li et al., 2016; Zhang and Ding, 1997). 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 (Wu et al., 2025a).

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). Surviving bamboo shoots that are not harvested grow into bamboo stem after the end of spring shooting (Shi et al., 2013). Moso bamboo stems reach their maximum biomass at age 4-5 years (Zhang et al., 2014; Zhuang et al., 2015) and mature at age 5-6 years (Yen and Lee, 2011).

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 provinces 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).

Bamboo shoots produced in Zhejiang, Hunan, Fujian, Jiangxi, and Sichuan provinces all compete for the same consumers (People.cn, 2014). Similarly, due to the high transportation costs and the initiatives to contribute to local economic growth, consumers of bamboo stems are generally local bamboo stem processing and manufacturing factories, and most of the bamboo stem are processed locally within each county (Zhang, 2003; Kusters and Belcher, 2004).

Bamboo shoots prices vary day to day and are hard to predict, while the bamboo stem price does not vary much over the course of a year. While winter shoots are more expensive than spring shoots, both winter shoots and spring shoots are more expensive than bamboo stem (Wu et al., 2025b). The costs of harvesting bamboo shoots and bamboo stem are 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).

3. Bamboo Cycle

The U.S. Department of Agriculture (USDA) defines the cattle cycle to be "a period of time that describes cattle producers' decisions to grow and decrease the size of their herds that collectively affect the size of the national cattle herd -- the total number of all cattle and calves" . The cattle cycle explains the contractionary and expansionary phases of the cattle industry at the macroeconomic level, impacted by price, input costs, and climate change factors (USDA, 2025). The cattle cycle is essentially an agricultural representation of a dynamic process that illustrates how interdependent products can affect each other, given uncertainty in prices and climate change. The total cattle inventory exhibited cattle inventory cycles every 8-13 years from 1938 to 2011 (Tonsor, 2011).

The management of a bamboo forest is similar to the management of cattle in several ways. First, both bamboo and cattle are renewable resources, meaning that they can reproduce without human intervention. Second, managers of both bamboo forests and cattle herds face uncertainty in input prices, profitability, and weather. Third, bamboo shoots and stems are interdependent products: while the products have different markets, the production and management of one product will affect the other. Interdependent products is also at the heart of cattle production: although calves and cows are raised and sold on different markets, harvesting one affects the other. Fourth, both cattle herds and bamboo forests involve biological growth processes and dynamic decision-making.

Since bamboo forest management is similar to cattle management, we establish the concept of a "bamboo cycle", similar to a cattle cycle. Figure 1 illustrates the bamboo cycle as a dynamic ecological and economic process driven by the dynamics and interdependence of bamboo stem and shoots growth, market factors, and environmental uncertainty. This cycle applies especially to Moso bamboo (*Phyllostachys edulis*), a major bamboo species in China.

Bamboo is a woody-grass plant that relies on both above-ground photosynthesis and its underground root system to develop. Thus, if a bamboo forest starts with more and better underground winter shoots, supported by favorable nutrition and conditions, then more high-value products can be harvested and contribute to bamboo farmers' income. The survival and quality of winter shoots depend heavily on precipitation and temperature during the shooting season, as well as the biological decay risk.

If winter shoots thrive, they lead to more and better spring shoots, which, although typically lower in market value, contribute significantly to forest regeneration and biomass growth. These spring shoots develop into more and better stems, which, when managed well, form the structural backbone of the bamboo forest. Over time, this results in a healthier bamboo forest, increasing the forest's capacity to produce high-quality shoots in future cycles. A healthier forest leads to higher nutrition levels and higher productivity, feeding back into the cycle with increased shoot emergence and overall ecosystem vigor.

Three forms of uncertainty disrupt this cycle, however. The first source of uncertainty is price uncertainty: volatile shoot and stem prices affect harvesting decisions, influencing shoot selection, regeneration patterns, and long-term forest structure. The second source of uncertainty is precipitation uncertainty: variable rainfall and climatic conditions impact shoot survival, especially during the sensitive shooting season, as well as the number of bamboo shoots that grow from bamboo stem at the beginning of each bamboo growth year. The third source of uncertainty arises from the possibility that shoots might not survive during shooting season.

Under price uncertainty and precipitation uncertainty, since harvests are irreversible, there may be an option value to waiting before harvesting that is akin to the option value to waiting in most problems of investment under uncertainty (Dixit and Pindyck, 1994). Thus, all else equal, a bamboo forest manager facing these forms of uncertainty may find it optimal to delay harvests. On the other hand, the opposite happens when there is uncertainty over the survival of bamboo shoots. Since shoots death is irreversible, all else equal, a bamboo forest manager facing the possibility that bamboo shoots may die may find it optimal to harvest earlier. Thus, a bamboo forest manager under uncertainty faces two different types of irreversibilities – in harvests on the one hand; and in death on the other – which leads to a tension between delaying versus expediting harvests (Wu et al., 2025a).

There are several trade-offs involved in determining the optimal bamboo shoots harvesting strategy that arise from uncertainty and the interdependence of shoots and stem. On the one hand, factors that may lead bamboo farmers to harvest shoots sooner rather than later include a high shoots price, low shoots harvest costs, and uncertainty over shoots survival. On the other hand, bamboo farmers may wish to delay the shoots harvest in order to give shoots more time to grow in biomass, and also to wait for the possibility of a higher shoots price (since shoots prices are uncertain). Furthermore, factors that may lead bamboo farmers not to harvest some or all of the shoots include low shoots prices, high shoots harvests costs; the desire for more bamboo stem the following year (since unharvested shoots 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 resulted 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. On the one hand, reasons to harvest bamboo stem sooner rather than later include high stem prices and low stem harvest costs. On the other hand, bamboo farmers may wish to delay harvesting bamboo stem in order to give the stem more time to grow in biomass; if stem prices are low; if stem harvest costs are high; to allow shoots to grow annually from the bamboo plant; and/or if they face uncertainty over precipitation, which affects how many shoots will grow from the stem remaining at the beginning of the year (Wu et al., 2025a).

The bamboo cycle is a coupled system of ecological growth and market response under uncertainty. It highlights how shoot and stem dynamics feed into long-run forest health, and how economic and environmental uncertainty influences decisions at each stage. As depicted in Figure 1, the bamboo cycle is a visual representation of the reinforcing mechanisms in bamboo production systems.

4. Implications for Producers and Policy

Just as the cattle cycle is challenging to cattle producers and policy, the bamboo cycle is challenging to bamboo farmers and policy.

The cattle cycle manifests itself in the cyclic nature of the US cow herd. One factor that likely influences the cattle cycle is the 9-month gestation, after which there is a period of approximately 6 months (give or take) before selling a small calf would happen. Thus, assuming some time is required to make the breeding decision, cattle producers are looking at a time period of 1.5 years or longer before they see a return.

For bamboo, the bamboo cycle manifests itself in the cyclic nature of the bamboo resource stock, as driven by the cyclic nature of bamboo stem harvests. Since bamboo shoots do not grow into bamboo stem until the end of the bamboo growth year, bamboo plants take one year before they become bamboo stem and are able generate new bamboo shoots each year, after which it takes at least 1.5 months before the bamboo shoots have enough biomass to consider selling. Moreover, bamboo stems reach their maximum biomass after 4-5 years. Thus, bamboo farmers are looking at a time period of 1.13 years or longer (when they begin harvesting bamboo shoots) before they see a return, and at least a few years before they consider harvesting the bamboo stem themselves. The cyclic nature of bamboo stem harvests is presented in Figure 2, which plots data we collected, translated, and transcribed from individual hard-copy handwritten Chinese records on bamboo stem harvests on 35 bamboo plots, each 20 meter by 20 meter in size, in Shanchuan Township and Sian Township in Zhejiang province in China from March 1, 2017 to August 31, 2018. As seen in Figure 2, bamboo stem harvests do not take place until the bamboo stem has aged 3 years or more.

Cattle production is also quite capital intensive, in addition to high risk (USDA RMA, 2023; Wolf and Karszes, 2023). The cattle cycle and the long time period (1.5 years or longer) before a cattle producer sees a return make risk management very challenging for cow-calf operations. Stand-alone cow-calf operations need to be quite large to manage this risk. As a consequence, many cow herds are part of a diversified crop/cow-calf farm or a sideline for a farm household with substantial off-farm income. The majority of small-scale cow-calf operations, defined as operations with fewer than 100 beef cows, rely at least partially on off-farm income to support the household (Gillespie and Whitt, 2024; Gillespie, Whitt and Davis, 2023; USDA, 2011).

Bamboo production is labor intensive, and the primary costs for managing a bamboo forest are labor costs (Wu et al., 2025b; Wu and Cao, 2016). Bamboo farmers in China are small peasants who own a relatively small amount of land per family; for many of these farmers, profits from bamboo harvests may not necessarily be their sole source of annual income (Wu et al., 2025b).

A primary driver of the cattle cycle is drought. Drought cycles have been common in primary US cattle production areas for a long time. To the extent that climate change increases drought length and severity, future cattle cycles and their associated challenges may be exacerbated by climate change.

Similarly, a primary driver of the bamboo cycle is precipitation, which affects the number of shoots that grow from bamboo stem at the beginning of each bamboo growth year, as well as the number of shoots that survive during the shooting season. To the extent that climate change affects the quantity, frequency, and variability of precipitation, future bamboo cycles and their associated challenges may be exacerbated by climate change.

From a policy perspective, the cattle cycle has important implications for food price inflation, land use impacts, and producer income. Producers have to balance wanting to maintain their herd (often a large investment) as much possible on the one hand, with maintaining the quality of pasture/rangeland -- which suffers long-term damage from overgrazing -- on the other.

The bamboo cycle likewise has important implications for forest management, food prices, timber prices, land use impacts, and farmer income. Bamboo farmers have to balance wanting to harvest winter shoots early for early profit, with maintaining their bamboo forest resource long term. Winter shoots have sometimes been over-harvested for high profit, leaving too few shoots for future bamboo forest development (Wu et al., 2025b).

5. Conclusion

We establish the concept of a bamboo cycle, similar to a cattle cycle. Bamboo is a very fast growing, renewable, versatile, and easy-to-grow resource touted for its environmental and sustainability benefits (Econation, 2025; Lewis Bamboo, 2025; Guadua Bamboo, 2025). The management of a bamboo forest is similar to the management of cattle; and the dynamics and interdependence of bamboo forest products share characteristics with the dynamics and interdependence of cows and calves. The bamboo cycle is a coupled system of ecological growth and market response under uncertainty that highlights how shoot and stem dynamics feed into long-run forest health, and how economic and environmental uncertainty influences decisions at each stage. Just as the cattle cycle is challenging to cattle producers and policy, the bamboo cycle is challenging to bamboo farmers and policy. By enhancing our understanding of the patterns and relationships in bamboo forest management, including the possibly periodic and cyclic nature of bamboo forest resources, stocks, and harvest decisions, the bamboo cycle provides valuable insights and helps guide the sustainable management of bamboo forests in particular, and the sustainable management of a wide variety of forests that generate interdependent products worldwide more generally.

References

Araujo, R., F.J.M. Costa, and M. Sant'Anna. (2020). Efficient forestation in the Brazilian Amazon: Evidence from a dynamic model. Working paper, FGV EPGE and University of Delaware.

Balboni, C., A. Berman, R. Burgess, and B. Olken. (2023). The economics of tropical deforestation. Annual Review of Economics, 15, 723-54.

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.

Blank, S.C., T.L. Saitone, and R.J. Sexton. (2016). Calf and yearling prices in the western United States: Spatial, quality, and temporal factors in satellite video auctions. Journal of Agricultural and Resource Economics, 41(3), 458-480.

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.

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

Crespi, J.M., T. Xia, and R. Jones. (2010). Market power and the cattle cycle. American Journal of Agricultural Economics, 92(3), 685-697.

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.

Dixit, A.K., and R.S. Pindyck. (1994). Investment under Uncertainty. Princeton University Press.

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]

Econation. (2025). Bamboo. Last accessed 31 August 2025. URL: https://econation.one/bamboo/

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]

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

Foster, K.A., and O.R. Burt. (1992). A dynamic model of investment in the U.S. beef-cattle industry. Journal of Business and Economic Statistics, 10(4), 419-426.

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

Gillespie, J., and C. Whitt. (2024). Beef cow-calf production continues to be a lifestyle choice for some farmers. Amber Waves, 26 August 2024. URL: https://www.ers.usda.gov/amber-waves/2024/august/beef-cow-calf-production-continues-to-be-a-lifestyle-choice-for-some-farmers

Gillespie, J., C. Whitt, and C.G. Davis. (2023). Structure, management practices, and production costs of U.S. beef cow-calf farms (Report No. ERR-321). U.S. Department of Agriculture, Economic Research Service. https://dx.doi.org/10.32747/2023.8134136.ers

Guadua Bamboo. (2025). Benefits of bamboo: 10 reasons why bamboo is the world's most amazing plant. Last accessed 31 August 2025. URL: https://www.guaduabamboo.com/why-bamboo

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.

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

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

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

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.

Krutilla, J.V., and M.D. Bowes. (1989). Economics and public forestland management. Natural Resources Journal, 29 (3), 737-749.

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).

Lewis Bamboo. (2025). Why bamboo? (Green solution). Last accessed 31 August 2025. URL: https://lewisbamboo.com/pages/why-bamboo-green-solution

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]

Lintunen, J., A. Rautiainen, and J. Uusivuori. (2022). Which is more important, carbon or albedo?: Optimizing harvest rotations for timber and climate benefits in a changing climate. American Journal of Agricultural Economics, 104, 134-160.

Marsh, J.M. (1999). The effects of breeding stock productivity on the U.S. beef cattle cycle. American Journal of Agricultural Economics, 8(2), 335-346.

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.

McKendree, M.G.S., T.L. Saitone, K.A. Schaefer. (2020). Cattle cycle dynamics in a modern agricultural market: Competition in Holstein cattle procurement. Working paper, Michigan State University and University of California at Davis.

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.

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.

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

Oldekop, J.A., K.R.E. Sims, B.K. Karna, M.J. Whittingham, and A. Agrawal. (2019). Reductions in deforestation and poverty from decentralized forest management in Nepal. Nature Sustainability, 2, 421-428.

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.

Reed, W.J. (1984). The effects of the risk of fire on the optimal rotation of a forest. Journal of Environmental Economics and Management, 11 (2), 180-190.

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.

Schulz, L. (2025). Repeating patterns help understand cattle cycle phases. Ag Decision Maker, 29 (4), 4-7.

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]

Sims, C. (2013). Influencing natural forest disturbance through timber harvesting: Tradeoffs among disturbance processes, forest values, and timber condition. American Journal of Agricultural Economics, 95(4), 992-1008.

Song, X., C. Peng, G. Zhou, H. Gu, Q. Li, and C. Zhang. (2016). Dynamic allocation and transfer of non-structural carbohydrates, a possible mechanism for the explosive growth of Moso bamboo (*Phyllostachys heterocycla*). Scientific Reports, 6, 25908.

Souza-Rodrigues, E. (2019). Deforestation in the Amazon: A unified framework for estimation and policy analysis. Review of Economic Studies, 86(6), 2713-2744.

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.

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

U.S. Department of Agriculture [USDA]. (2011). Small-scale U.S. cow-calf operations. USDA–APHIS–VS, CEAH. #596.0411. Accessed 11 September 2025. URL: https://www.aphis.usda.gov/sites/default/files/small_scale_beef.pdf

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

U.S. Department of Agriculture [USDA] Risk Management Agency [RMA]. (2023). First of its kind risk management tool for cow-calf producers. Morning AgClips, 1 October 2023. URL: https://www.morningagclips.com/first-of-its-kind-risk-management-tool-for-cow-calf-producers/

Wang, H., G.S. Amacher, and J. Xu. (2025). The social cost of fiscal federalism and the depletion of China's native forests. Working paper, Virginia Polytechnic Institute and State University.

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.

Wolf, C.A., and J. Karszes. (2023). Financial risk and resiliency on US dairy farms: Measures, thresholds, and management implications. Journal of Dairy Science, 106 (5), 3301-3311.

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). Bamboo management, economics, and finance: Evidence from Moso bamboo farmers in China. 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]

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.

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.

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 Cycle

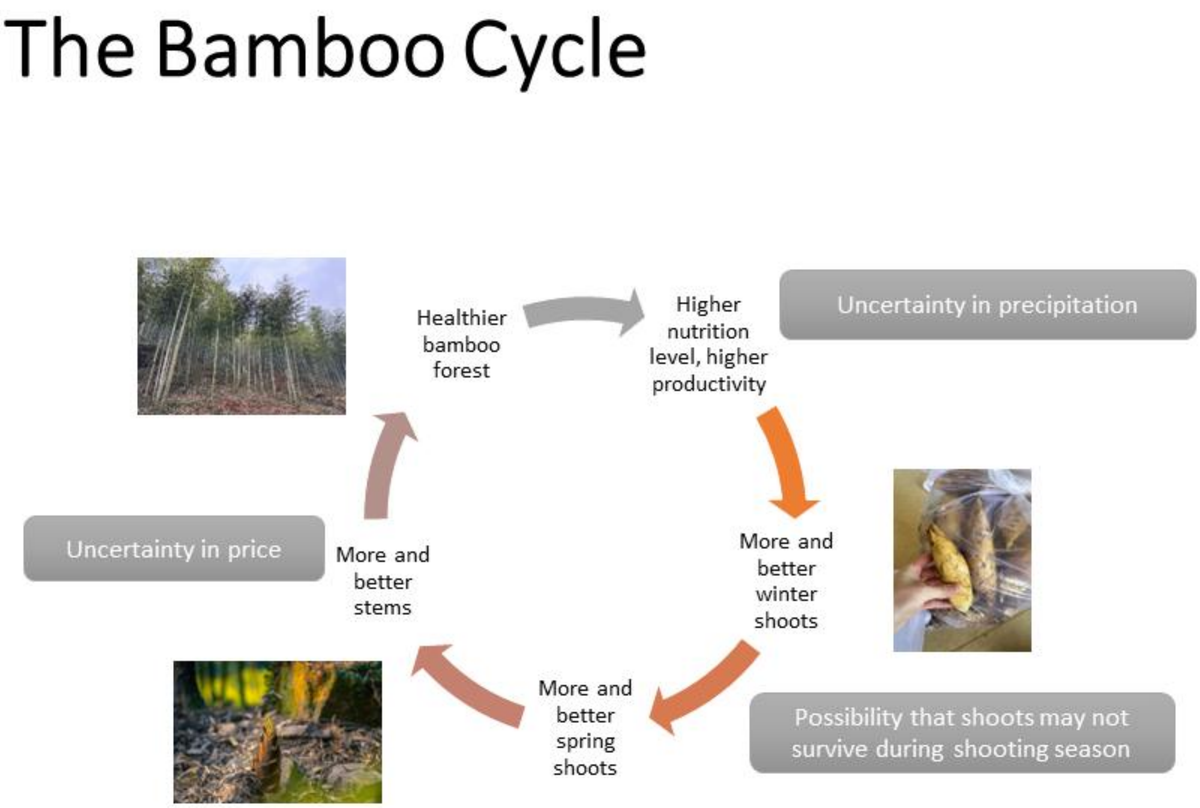
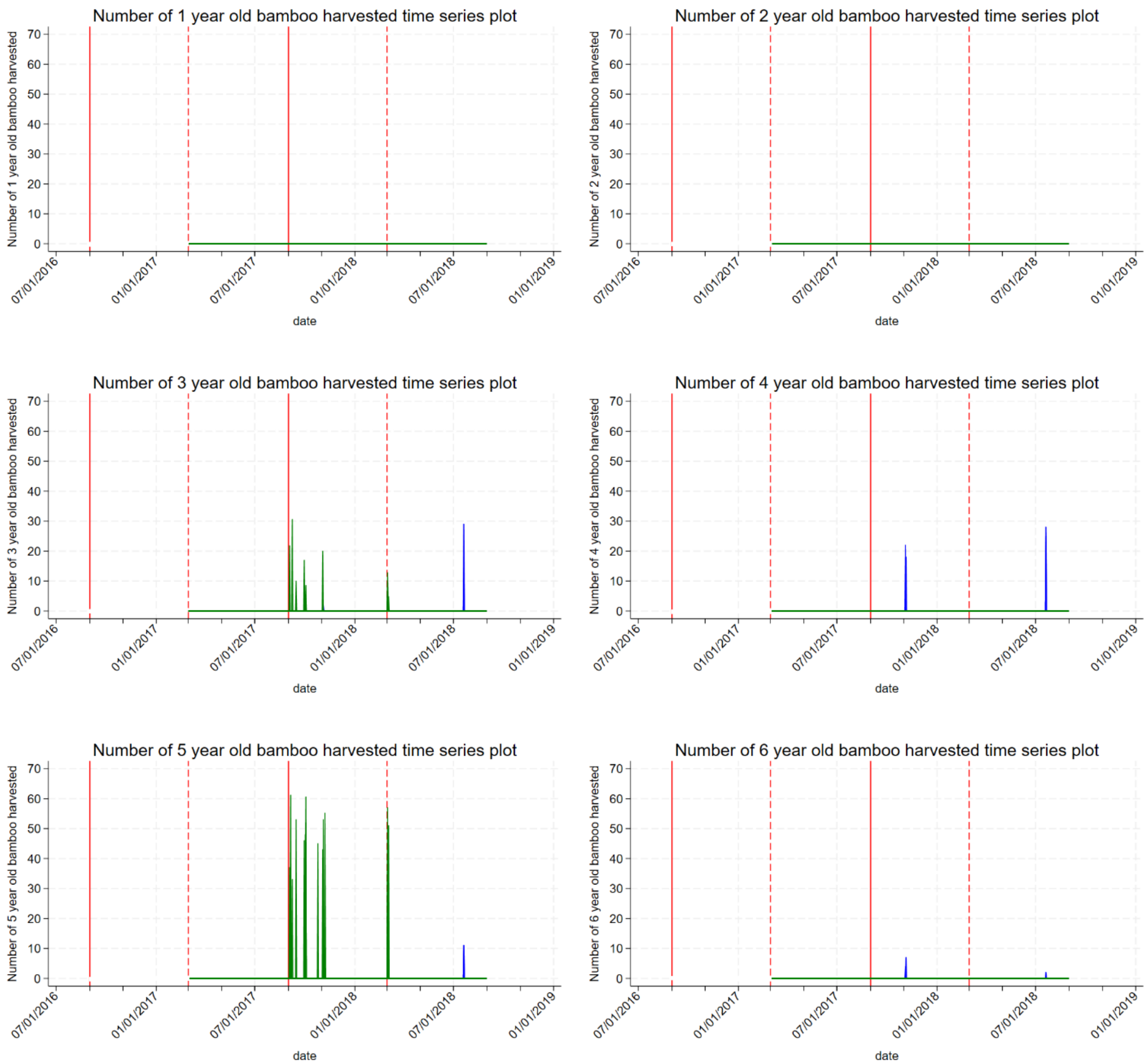


Figure 2. Cyclic Nature of Bamboo Stem Harvests



Notes: Time series plots of the number of bamboo stem harvested by age of bamboo stem. Vertical lines in red that go from the top to the bottom of the graph denote September 1 (first day of winter shooting) of each year. Dashed vertical lines in red that go from the top to the bottom of the graph denote March 1 (first day of spring shooting) of each year. Data are collected, translated, and transcribed from individual hard-copy handwritten Chinese records on bamboo stem harvests on 35 bamboo plots, each 20 meter by 20 meter in size, in Shanchuan Township and Sian Township in Zhejiang province in China from March 1, 2017 to August 31, 2018.