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RESEARCH ARTICLE

Dynamics in production of four heritage foods at the mountainous region of Shaoxing City, China

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ABSTRACT

Agricultural heritage foods play important roles in sustainable agricultural development in mountainous regions because they are key income sources and represent an integration of human culture and natural landscape. With the dramatic change in socioeconomic and natural systems in China, the production of heritage foods from mountainous regions might be affected. In this study, the dynamics of production for four heritage foods including dried tender bamboo shoots, chestnuts, Torreya and tea at the mountainous region of Shaoxing City in China from 2001 to 2016 were examined and analyzed. The results indicated that tea, dried tender bamboo shoots, chestnuts, and Torreya were ranked at 1st, 2nd, 3rd and 4th in the average production. There were significant correlations between the coefficient of variation (CV) of annual average air temperature and the CV of production in dried tender bamboo shoots, and also between the CV of annual air temperature (or precipitation) and the CV of tea production. Regime shift occurred in the production of each heritage food based on multiscale entropy and Taylor's law. These results provide useful information for the dynamics of agricultural livelihood from mountainous regions and the development of heritage foods in modern society.

Keywords: Climate; Livelihood; Multiscale entropy; Regime shift; Taylor's law

INTRODUCTION

The economic growth in China was high during the recent decades. This fast economic growth brings dramatic changes in socioeconomic and natural systems in China, especially to mountainous regions, where provide indispensable goods and services (e.g., foods, water) to a significant proportion of human society (Rasul and Hussain, 2015). More people migrated from rural or mountain regions to urban areas to improve or secure their lives (World Bank, 2016). Young people would like to stay in cities while older people have to still live in mountainous regions due to job and income issues (Ye et al., 2010). The migration and population change also changed household consumption patterns and created "remittance landscapes", where the traditional type of crop such as paddy field has been changed to beans, due to labor and water shortages (McKay, 2005).

Such changes are recorded in the food, culture and the landscapes of mountainous regions that have continuously evolved. Food culture usually refers to the practices, attitudes, and beliefs as well as the networks and institutions related to the production, distribution, and consumption of food. It is considered to arise from people's origin and influenced by environmental conditions (e.g., land, climate, and water), religion, education and literacy, ethnicity (e.g., indigenous or immigrant), technology (e.g., cooking and agriculture), and also health condition (Wahlqvist and Lee, 2007). Thus, heritage foods may constitute an important factor in the sustainable development in mountainous regions by providing significant economic income based on traditional food knowledge. However, with the rapid change of most relevant factors, such as population migration, the interest for available and affordable food culture may be changed or even lost. For example, people pay more attention to healthy foods or choose to work on other business. As foods and cooking may reflect the social and cultural conditions, China has become the most significant wine export market of the European Union during the recent years (Bessière, 1998; Wang et al., 2015).

The traditional food culture in the Shaoxing City of China is vibrant due to its human population, mild climate,

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and long history. Shaoxing is located at a subtropical monsoonal climate zone in China, where it is hot and humid in summers and cold and wet in winters. The environmental condition and human history in this region result in some unique plants to grow. There are abundant natural vegetation and plantations, such as bamboo, tea, chestnut, and Torreya grandis (Fig. 1). Tea is considered as a healthy beverage. It is loaded with antioxidants and nutrients which have sound effects on the human body. Tea and its related products are also popular globally. Bamboo is a food source of antioxidants and regular consumption of bamboo products could decrease the risk of chronic diseases, such as cardiovascular diseases, cancer, Parkinson's disease, Alzheimer's disease, and diabetes (Nirmala et al., 2018). Dried tender bamboo shoots are easy to be preserved and can be used late at any time. Chestnut is a valuable functional food. Recently it is recognized for high nutritional quality and potential health benefits. Chestnut is a part of gluten-free diets (Pazianas et al., 2005), which are helpful in preventing cardiovascular disease (Sabaté et al., 2000). The processed nuts of Torreya grandis have been used by local people as food for more than a thousand years. Its nutrients include protein, unsaturated fat, amino acids, minerals, and vitamins (Li and Dai, 2007; Chen and Jin, 2019a,b). The nuts could be used to produce varieties of food, such as cakes, candy, and shortbread after being fried, and also drinks (e.g. wine and juice). Torreya oil can selectively decrease cholesterol and glycerin trilaurate, and increase high-density serum lipoprotein cholesterol. The four types of lipo-alkaloids can suppress lymphatic leukemia and is useful to prevent and treat malignant lymphosarcoma (Chen and Jin, 2019a). These food products are popular and always be exported to international markets (People's Government of Shaoxing City, 2013).

Under the influences of urbanization, agricultural industrialization and agricultural commercialization, agriculture practices and food production were gradually changed. Farmland use intensity in Zhejiang Province was changed (You et al., 2018), which indicated that urbanization and economic development could significantly influence the sustainable agricultural development at a large scale. Perez et al. (1999) analyzed the farmer's income at Anji County in Zhejiang Province and found that bamboo shoots accounted for about 10% of the contribution. Li et al., (2012) evaluated the land suitability for tea crops based on climate and other environmental resources. Most studies on chestnut and Chinese Torreya were concentrated in the chemical composition (e.g., Yang et al., 2015; Duan et al., 2017). So far, there are few studies on the production dynamics of these heritage foods. Bellandi and Lombardi (2012) indicated that local specialized markets and industrial clusters in Zhejiang Province was a driving force of transition from a rural to a market economy. Thus, the change in the production of different heritage foods in recent decades may reflect the interactions of culture, economics, policy, natural resource, and environment. The overall goal of this research is to study the dynamic patterns of production change in these four heritage foods during 2001-2016, a period under the dramatic economic growth in the mountainous region of Shaoxing, and examine their correlations to each other and main climate variables such as air temperature and precipitation. The specific objectives include (i) did the production of these heritage foods change over time? Were they correlated to each other? (ii) did a growing trend exist in the production of these foods during this period? Did they have a similar pattern or not? And (iii) did they have a same or different regime change? The results of this study will provide insights and useful information of the heritage food production for

Fig 1. The four heritage foods and the landscape in Shaoxing City.

local land management and sustainable agricultural and food development.

MATERIALS AND METHODS

Shaoxing mountainous region and heritage foods

Shaoxing City is located in northeastern Zhejiang Province in eastern China with a long civilization history (Fig. 2), which includes Shaoxing County, Zhuji City, Shengzhou City, Xingchang County, and Shangyu City. Shaoxing is the commercial hub of a rich and productive agricultural area where people know how to drain and irrigate from very early times. In the 7th century BCE, Shaoxing was the capital of the state of Yue. Local people started to produce high-quality tea at that time. In the 1980s, Shaoxing developed into one important textile-manufacturing city in the nation because of high-quality cotton and silk. Other industries included food processing and machinery making. Shaoxing is listed as one of the nation's historical and cultural cities (www.britannica.com/place/Shaoxing).

The northern part of Shaoxing City is comprised of plains, with valleys and mountains in the central and southern areas. Mountains cover about 95% of the total area. The highest peak is at Dongbaishan with the elevation of 1194.6 meters. The mountainous region (also known as Kuaijishan) is the central distribution area of Torreya grandis, which are in Zhuji, Shaoxing, and Shengzhou within Shaoxing City (Li and Dai, 2007; Chen and Jin, 2019b). These mountainous regions cover approximately 20 thousand hectares of Torreya grandis, which accounts for over 80% of national Torreya production. The Ancient Chinese Torreya Community has more than 2000 years of history and the age of the Chinese Torreya trees was traced back to 1431 (People's Government of Shaoxing City, 2013; Chen and Jin, 2019a,b). The bamboo forest is native vegetation in the mountainous region. Bamboo shoots are easily available for common people to get nutrition (Tripathi, 1998). The bamboo shoots have high nutritive content, such as high-quality vitamins, carbohydrates, proteins, and minerals. Some easy processing practices (e.g., drying, soaking, or boiling) can remove the cyanogenic glucosides and make bamboo shoots palatable and safe to eat (Nirmala et al., 2018). Dried tender bamboo shoots (short name as dried bamboo) are preserved food from local people. Dried tender bamboo shoots can be made for many Chinese gourmets, such as braised pork belly with dried bamboo shoots. Chestnut trees have a growing history of more than 2000 years in China, and the local chestnuts had the highest polyphenol content (Yang, 2015). Chestnuts are free of cholesterol and also contain considerable amounts of fibers, ascorbic acid, and trace minerals (Gold et al., 2005). They can be consumed as nuts, cake, and also gourmets.

Statistical analysis

The data on production for the dried tender bamboo shoots, chestnuts, Torreya grandis, and tea from 2001 to 2016 were collected from the published local government reports, such as yearbooks and annual reports from the city government. The average and coefficient of variation of production (CV) for each of four heritage foods from 2001, 2002…2016 across the entire region were calculated with a time scale of 1, 2, 3…15 years. Both the average and CV of each heritage food were calculated by the moving time window (Chen et al., 2018). Climate data were collected from the weather stations in Shaoxing. The overall annual air temperature, precipitation and CVs across the

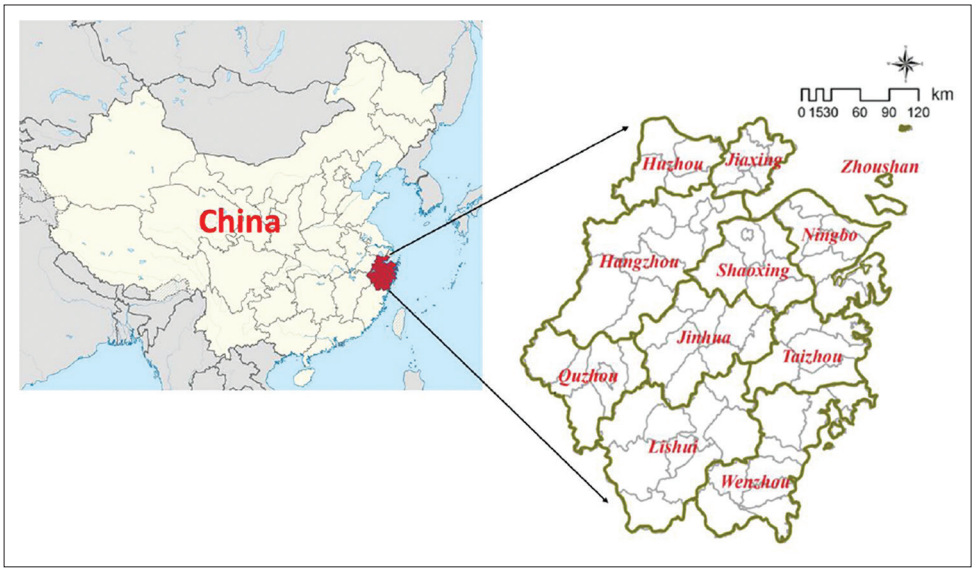

Fig 2. Location of Shaoxing City in Zhejiang Province of China.

region were also calculated with the moving time window. Spearman's correlation was conducted by SAS software (Version 9.3, SAS Institute Inc., Cary, NC, USA) with the statistical significance at $p < 0.05$.

Taylor's Law

Taylor's law is an empirical law in ecology which links the variance of the individual number for a species in a habitat area to its corresponding mean by a power-law relationship (Taylor, 1961).

In this study, Taylor's law can be expressed in the following equation:

$$variance = a \times Mean^{r}$$

Where variance stands for the variance of production in one heritage food, *Mean* as the average of food production. After logarithm, $log\ (Variance) = log\ (a) + r \cdot log\ (Mean)$. With the time increase of 1, 2 …. to n-1 years from the first available production record, the linear relationship between the log(average) and log(variance) of food production was estimated for each heritage food by correlation (Chen et al., 2017). Any deviations may indicate disturbance or regime shift.

Multiscale entropy

Multiscale entropy is a method used for analyzing the complexity of nonlinear and nonstationary signals in finite-length time series (Chen et al., 2005). In this study, multiscale entropy was calculated through the Shannon entropy ($H_{\varepsilon}(x)$) of food production at different time scales of ε (length of years) as the following:

$$H_{\varepsilon}(x) = \sum p_{\varepsilon}(x)\, LOG_{10}\, p_{\varepsilon}(x)$$

Where $P_{\varepsilon}(x)$ is the percentage of one food production (x) at the ith year measured using samples of ε units in size. The time scale of ε includes 1, 2... m/2 or (m – 1)/2.

The percentage at different time scale (ε) is calculated by the following approach:

$$p_{\varepsilon}(y) = \frac{y_i}{\sum y_i} \times 100$$

Higher values of entropy represent higher temporal evenness of the food production at the time scale of ε years. If all the entropy values across different time scales can be fit by a straight line, no regime shift of production is suggested (Chen et al., 2005).

RESULTS

Tea had the highest annual production (about 50,000 tons), and Torreya had the lowest annual production (about 4,000 tons) among these four heritage foods (Fig. 3). The annual production of Torreya was only about 1/10 of the production of tea, while the annual production of

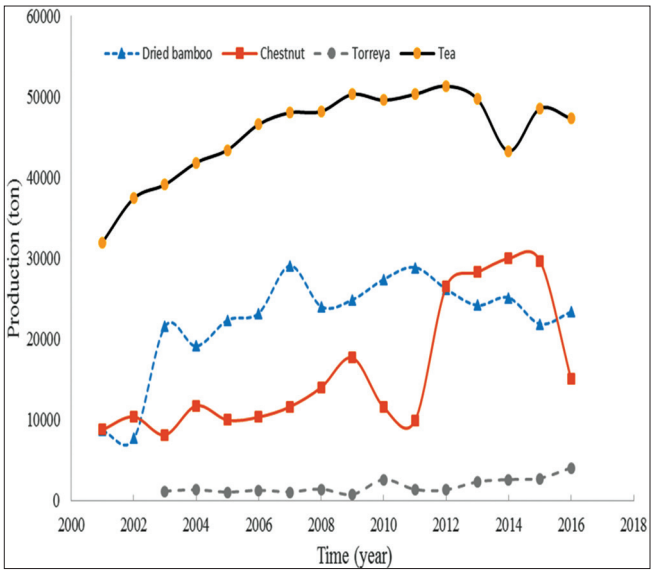

Fig 3. Dynamics of annual production in the four heritage foods in Shaoxing.

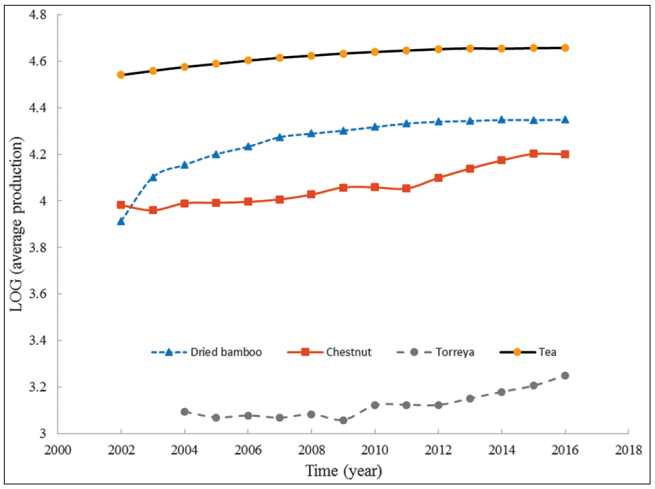

Fig 4. The average production by a moving window for the four heritage foods in Shaoxing.

Table 1: Relationship between time (year *x*) and the average production (ton Y) by a moving window for each heritage food

Heritage foods	Relationships	R^2 and p values
Dried tender bamboo shoots	Y=2E+06ln(x)-1E+07	R^2=0.8348, p<0.01
Chestnuts	$Y=2E\text{-}265x^{81.394}$	R^2=0.9178, p<0.01
Torreya	$Y=2E\text{-}24e^{0.0307x}$	R^2=0.7757, p<0.05
Tea	Y=2E+06ln(x)-1E+07	R^2=0.9172, p<0.01

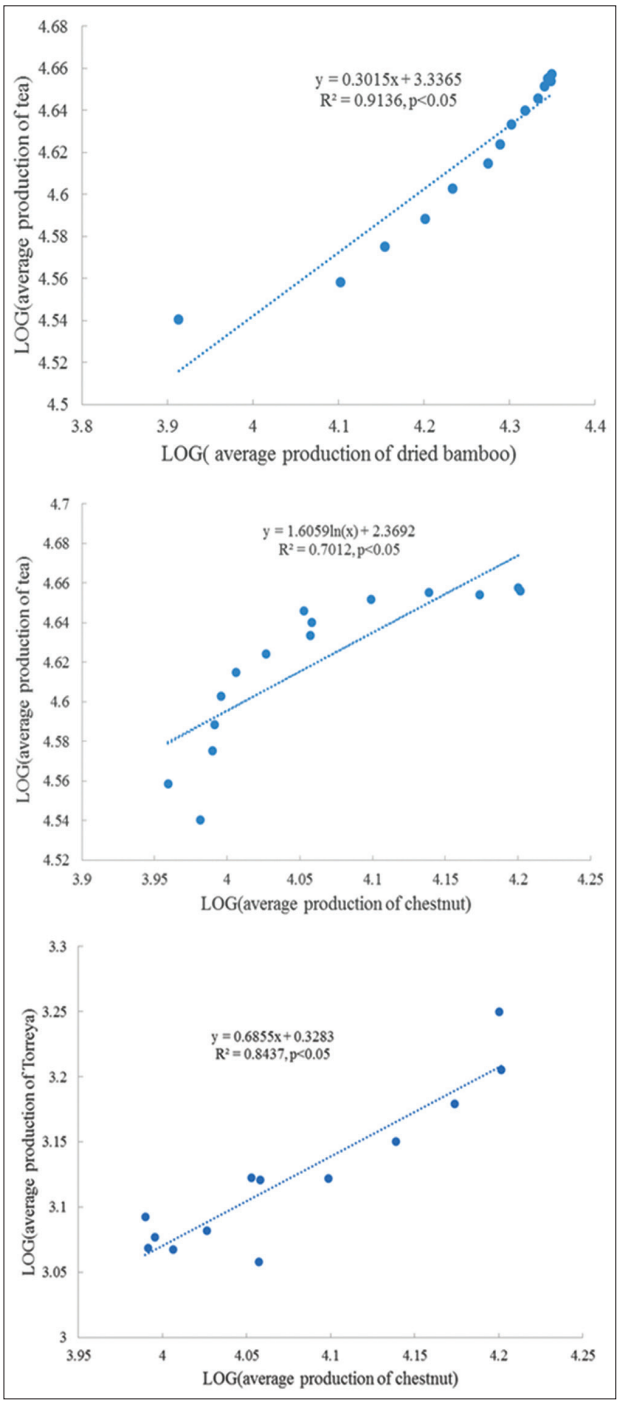

Fig 5. Correlation between the average productions of heritage foods in Shaoxing. (a) Dried bamboo vs Tea; (b) Chestnut vs Tea; and (c) Chestnut vs Torreya.

dried bamboo and chestnuts was about ½ and 1/3 of the tea's production, respectively. The annual production of chestnuts increased dramatically during 2012-2015 and passed over dried bamboo, but it decreased after that period.

The average production by the moving window for the four heritage foods still increased with time (Fig. 4). Tea,

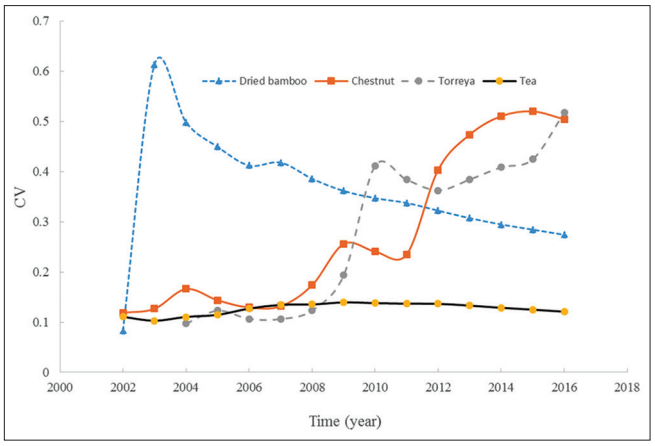

Fig 6. The CV of production for the four heritage foods in Shaoxing.

dried bamboo, chestnuts, and Torreya were ranked at 1st, 2nd, 3rd and 4th in average production by moving windows. There was a sudden increase in the average production by the moving window for chestnuts and Torreya after 2010-2011. There were nonlinear relationships between time and the average production by the moving window for each heritage food (Table 1). Significant correlations existed between the average productions by the moving window at dried bamboo vs tea, chestnuts vs tea, as well as chestnuts vs Torreya (Fig. 5).

There were fluctuations in the production of these four heritage foods by the moving window (Fig. 6). Tea had the lowest and most stable CV in the four heritage foods. Dried bamboo once had a higher CV, but recently Torreya and chestnuts had a higher CV. There were significant correlations between the CV of annual air temperature or annual precipitation and the CV of the tea production (Fig. 7). However, there was only a significant correlation between the CV of annual air temperature and the CV of dried bamboo production. But for chestnuts and Torreya, the correlations between the CV of production and the CV of annual air temperature or annual precipitation were not significant.

The dynamics of multiscale entropy were similar among four heritage foods (Fig. 8). It changed smoothly, but transition occurred beyond the time scale of 5 years. This indicated there was a regime shift in the production of each heritage food. Comparing Taylor's power law of each heritage food (Fig. 9), it was apparent to see the regime shifts in dried tender bamboo, Torreya, and tea.

DISCUSSION

The heritage foods are not only just food, but also a part of a psycho-sensorial, social, and symbolic environment. They have both nutritional values and symbolic

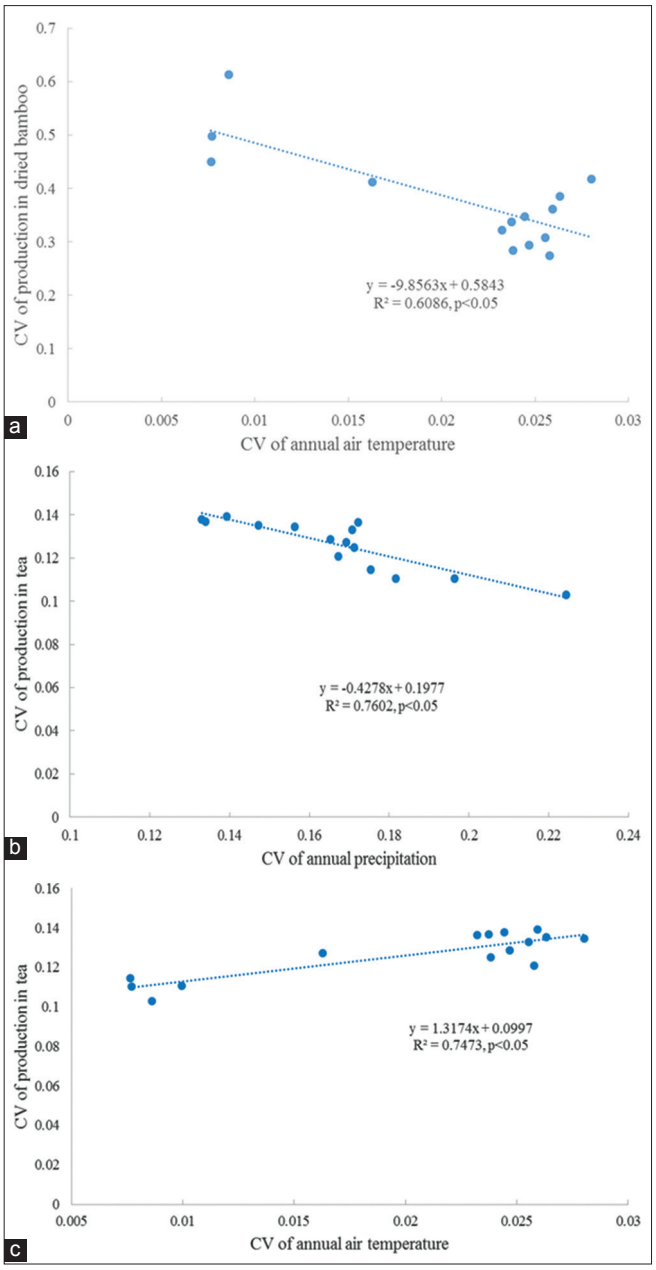

Fig 7. Correlation between the CV of climate and CV of food production in Shaoxing. (a) The CV of air temperature vs CV of production in dried bamboo; (b) The CV of annual precipitation vs CV of production in tea; (c) The CV of annual air temperature vs CV of production in tea.

characteristics (Fischler, 1993). Selling heritage foods in agriculture (including forestry) usually is the primary income for most local people in mountainous regions (IBRD/World Bank, 2007). Developing heritage foods is a practical approach to reducing poverty and will still play a critical role in efforts to develop the local economy in mountainous regions (Christiaensen et al., 2011). Also, promoting heritage foods may provide economic opportunities for rural women in mountainous areas, who can directly involve in harvesting, processing, and marketing. With this background information, it may be

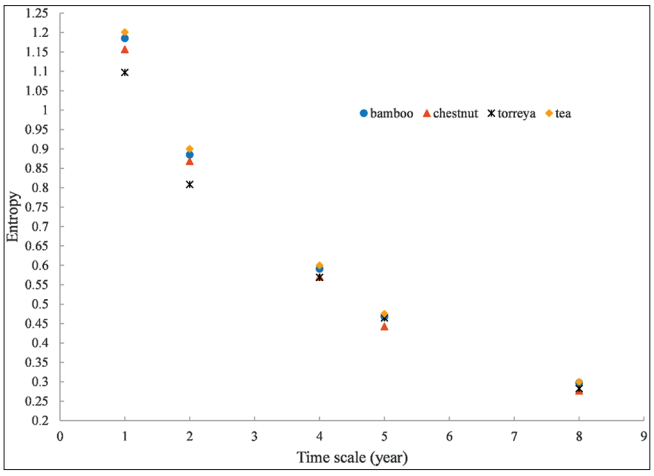

Fig 8. Multiscale entropy of the production for the four heritage foods in Shaoxing.

helpful to understand the patterns of production in four heritage foods in Shaoxing City.

Tea, dried bamboo, chestnuts, and Torreya were ranked 1st, 2nd, 3rd, and 4th in the average production from 2001 to 2016. Tea dominated the production, which might be related to its popularity, extent and long history of developing tea gardens in China. Tea drinking is prevalent in China. It is similar to coffee in the western world. Local people have the knowledge of developing different tea products for profit. The bamboo forest is a native vegetation type in this mountainous region. It is natural to harvest tender bamboo shoots in the springtime to produce dried tender bamboo shoots. Although Torreya grandis existed in the region for more than a thousand years, the area of Torreya grandis was very limited, which led to its low production. Only during the recent decade, its plantations started to be established (Chen and Jin, 2019b). There are several key factors that influence the plantations (People's Government of Shaoxing City, 2013; Chen and Jin, 2019a). (i) Long-time investment: it usually takes 10~20 years for young trees to start seed production. During this period, there are only capital and labor inputs without profit in return. Thus, a large amount of financial support is needed to establish new plantations; (ii) Labor requirement: it is a labor-intensive business to develop plantations and manage Torreya grandis trees, including weed control, seeds harvesting and nuts processing (Li and Dai, 2007; Chen and Jin, 2019a). Since Torreya trees are tall, it is also dangerous to pick up seeds, especially for those trees growing at steep slope areas; and (iii) Lack of knowledge: most farmers do not have sufficient knowledge of diseases and pest management for Torreya trees. Local people once cut down a large amount of male trees for timber because these trees did not produce seeds. This led to insufficient pollination and low seed production. The mechanisms for the correlation between the average productions among

these four heritage foods are not clear, but it might be related to land use or working time, which means farmers or householders would like to make maximum profit from different foods in different seasons. The time for picking up tea or tender bamboo is in early spring (e.g., from March to May), but harvesting and processing chestnuts or Torreya is in fall (e.g., September and October). Keeping some of these together may make business running year-round and earn more profit.

The dynamics of CV for each heritage food production also might be related to the market demand. The CV of tea or dried bamboo was stable and saturated, but the demand for chestnuts or Torreya was always high. The correlation between the CV of production in these heritage foods and the CV of climate might indicate the limitation of climate fluctuation. The change in the production of dried bamboo was negatively related to air temperature change. When the air temperature is high, bamboo shoots grow fast, and it is not easy to quickly harvest bamboo shoots when they are tender (young). However, the increase in air temperature might increase the production of tea, too much rain could prevent people from harvesting tea, or the wet condition might deteriorate the quality of collected tea. For chestnuts and Torreya, the relationship between the CV of production and CV of climate seemed complicated. Climate change, therefore, may affect these food supplies and nutrition security for people living in the vulnerable ecosystems (Campbell et al., 2016). The results support that agricultural production is highly connected to the environment, management of natural resources, and climate change (Smith, 2013). The results also indicate that it is necessary to develop the capacity of changes for small farmers and producers in heritage foods to mitigate to climate change as well as to help food producers to adapt to changed climate.

The dynamics of multiscale entropy of these four heritage foods indicate regime shift in their production, especially when the time scale is more than five years. From Taylor's laws, it also shows the regime shift for dried bamboo after 2003, Torreya after 2009, and tea after 2010. The regime shift in the production of these heritage foods might be related to all factors, such as price, cost, government policy, market, and climate. The high price of Torreya and increasing market demand stimulated its production. The oversupply of tea might lead to a decrease in its production during recent years. There are numerous reasons that the heritage food systems should evolve and shift from an exclusive focus on the increase of production (Caron et al., 2018). New development in food science will also bring new opportunities for food plants, such as Torreya fruits have biomedical ingredients while bamboo leaf antioxidants are very effective in preventing biogenic amine formation in pork sausage when combined with tea polyphenols (Fan et al., 2015). Heritage food systems should be designed so that they contribute to eradicating poverty and achieving sustainable development (Haddad et al., 2016). Given the constant evolution of culture and society, the demand for food with the function of wellbeing and health is increasing (Kumar et al., 2017). There is always more knowledge to be learned about the links between agriculture, climate, food, nutrition, ecosystem regeneration (e.g., old tea garden and old Torreya or chestnut trees), and humanity.

CONCLUSION

Under the changing socioeconomic and climate condition in Shaoxing City, there existed fluctuation in the production of four heritage foods. But the average production for the four heritage foods still increased with time. Correlations existed between the average productions in different heritage foods. Climate fluctuation was significantly correlated to the production variations in tea and dried bamboo. Regime shift was detected in the production dynamics of each heritage food. All these four heritage foods (or drink) in the mountainous region of Shaoxing City can serve as a new ingredient for the production of healthier food products. Also, they can be used for fortifying various food products. Therefore, the production of these heritage foods will continue but will fluctuate with the market and environmental conditions. Understanding the dynamics in the production of these heritage foods can provide an emergent pattern of agricultural development in this region for the local government and relevant organizations. This study may provide a new effort to study the dynamics of heritage foods from an integrated perspective. The strategies to adapt to climate change should be based on the climate effects and others from scientific research. It is necessary for the local land managers and householders to manage their land for sustainable food development properly.

Author Contributions

XC collected the data. XC and HC designed the study and wrote the manuscript.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

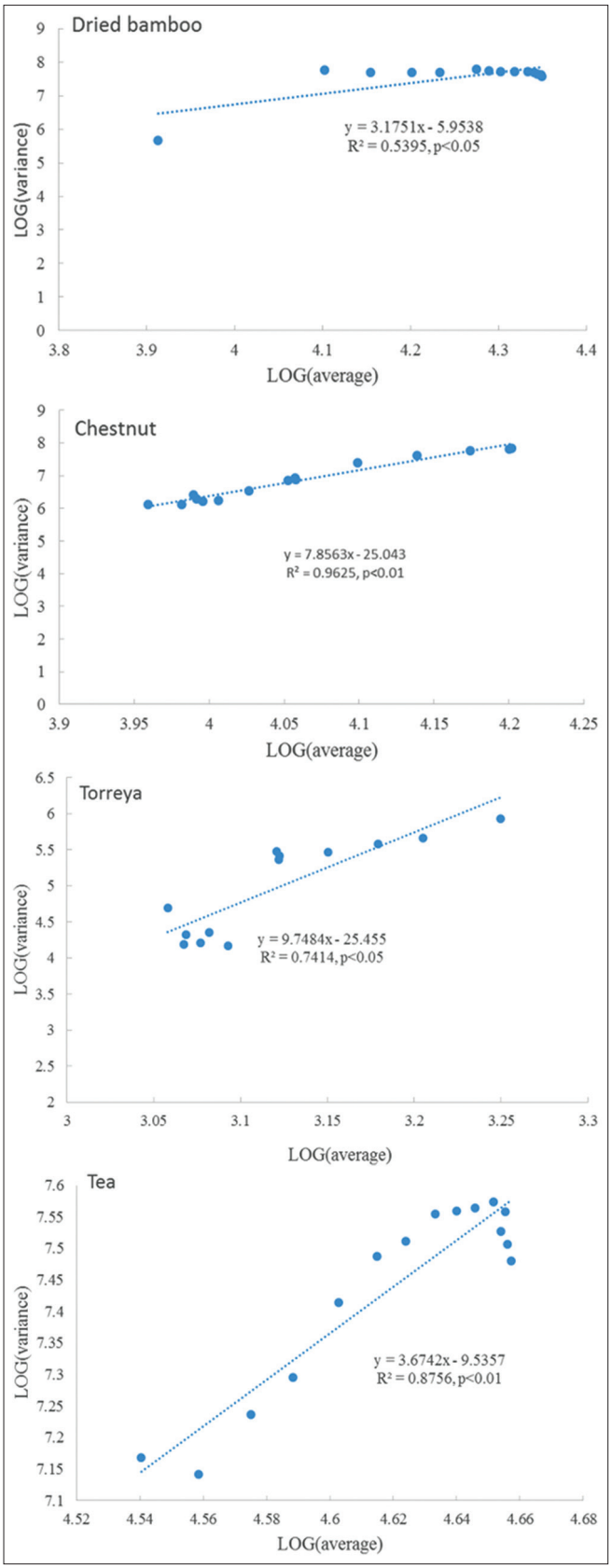

Fig 9. Taylor's power law in the production of four heritage foods in Shaoxing.

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