

Article ID: 9203
DOI: 10.5586/asbp.9203

Publication History

Received: 2022-07-20
Accepted: 2022-10-28
Published: 2023-03-02

Handling Editor

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Authors' Contributions

LCL conceived and designed the study; CZ, FYX, LXP, FQ, LYC, and HZJ collected data; LCL, LYC, HZJ, and CZ identified plants; CZ interpreted and analyzed the data and wrote the manuscript; LCL, FYX, LXP, FQ, and LBS have modified the manuscript

Funding

This work was supported by grants from the Minzu University of China (2022GJJAQ04, BZKY2022041, and 2020MDJC03), the Biodiversity Survey and Assessment Project of the Ministry of Ecology and Environment of China (2019HJ2096001006), and the National Natural Science Foundation of China (No. 31761143001 and 31870316).

Competing Interests

No competing interests have been declared.

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RESEARCH PAPER

Traditional ecological knowledge of bamboo in the Dulong community of northwestern Yunnan, China

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Abstract

The Dulong people have accumulated a wealth of traditional botanical knowledge (TBK) over a long period on bamboo use to adapt to their living environment, which impacts many aspects of the life, culture, and creative productivity of the Dulong people. However, research on TBK associated with bamboo in Dulong communities is still lacking. It is urgent to investigate and document the TBK related to bamboo in the context of rapid economic development and social changes in Dulong communities. Field surveys were conducted four times between 2019 and 2020. Thirty informants were selected using snowball sampling and were interviewed using free lists and semi-structured interviews. Most informants were or had been engaged in bamboo collection and weaving. The participatory observation approach has also been applied to field surveys. The use value (UV) of bamboo species and the relative frequency of citations (RFC) were used to evaluate and compare the importance of bamboo plants used by the Dulong people. Through ethnoecological investigations, 12 bamboo species belonging to seven genera traditionally used by the Dulong people and TBK associated with bamboo were recorded. *Phyllostachys sulphurea*, *Dendrocalamus fugongensis*, and *Fargesia pleniculmis* were the most valuable and favored species, as indicated by their relatively high RFC and UV indices. The Dulong people have accumulated a wealth of TBK associated with bamboo and are familiar with the distribution, ecology, morphology, characteristics, and purpose of bamboo species in the Dulongjiang region. These bamboo plants and their traditional knowledge have great potential for conserving the local biodiversity and sustainable development. In the future, we will increase the growth of industries related to bamboo plants, such as bamboo shoots as food, bamboo as medication, bamboo for the weaving industry, and bamboo for biocultural diversity conservation.

Keywords

bamboo; ethnoecology; ethnobotany; sustainable development; traditional botanical knowledge

1. Introduction

With continued population growth and increasing urbanization, forest resources, including wood, are facing crucial challenges for sustainability (Lin et al., 2019). Over the last few decades, bamboo has increasingly replaced timber for industrial use, reducing the pressure for forest clearing (Peng et al., 2013; Sharma et al., 2015). Bamboo products are used widely in construction, furniture, papermaking, packaging, pharmaceutical, food, textiles, and craft in developing countries (Felisberto et al., 2017; Lu et al., 2018; Shen et al., 2019). As an important non-timber forest product, bamboo is a multipurpose and sustainable resource with great potential for promoting employment and income in rural communities (Endalamaw et al., 2013). It can be a meaningful nature-based contributor to solving a few pressing global challenges of poverty alleviation, green trade, climate change mitigation and adaptation, resilient construction, and environmental protection (Dai & Hwang, 2019).

Bamboo is a group of fast-growing plants belonging to the Bambusoideae family of Gramineae, with approximately 121 genera and 1662 species (Canavan et al., 2016; Lee et al., 2021; Piazza et al., 2007). As the largest producer, consumer, and exporter of bamboo products, China has excellent bamboo diversity, with more than 40 genera and 800 species (International Bamboo and Rattan Organisation, 2020). In addition, China is a multiethnic country with a long history and a diverse and colorful ethnic culture. In the long cultural history and living practices of different linguistic groups, enormous traditional botanical knowledge (TBK) associated with bamboo has been generated (Guan, 2008; Yang et al., 2008). The TBK related to food, medicine, textiles, handicrafts, construction, and culture plays an irreplaceable role in the economy and livelihoods of local people, promotes local ecological protection and ecosystem services, and provides a knowledge base for finding new medicines, foods, and biomaterials (Li & Weng, 2017; Quave & Pieroni, 2015; Siddique et al., 2021). Therefore, a comprehensive investigation of TBK concerning bamboo can help regional economic development, local biodiversity conservation, ecologically sound practices, and future sustainable development (Luo et al., 2020).

Previous studies on the bamboo culture of the Dai, Hani, Yi, Wa, and Lisu ethnic groups have shown that local people have rich TBK in the recognition, classification, utilization, and management of bamboo, which has promoted the protection and sustainable development of local forests (He & Liao, 1999; He & Xiong, 2010; Li et al., 2015; Long et al., 2002; Tian, 2009; Wang et al., 1991). Bamboo products are a necessary means of poverty alleviation in remote communities (Arun et al., 2015; Phimmachanh et al., 2015).

Yunnan Province is the center of traditional bamboo culture in China, with high ethnic and cultural diversity and abundant bamboo plant species diversity (Yang et al., 2004a, 2004b). Dulong (or Drung), the smallest ethnic group in Yunnan, is mainly distributed in the Dulongjiang area of Gongshan Dulong and Nu Autonomous County, Nujiang Lisu Autonomous Prefecture, Yunnan (Geng et al., 2017). Owing to a long history of interaction with nature and the unique topography, e.g., isolation due to steep mountains, over-raining, inaccessible transportation, and abundant natural resources, the Dulong people have developed many unique livelihood strategies, such as collecting wild edible and medicinal plants, hunting, beekeeping, slash-and-burn agriculture, and fishing practices (Cheng et al., 2020, 2022a, 2022b). The Dulongjiang area is one of the most abundant regions in bamboo resources in China (Du et al., 2013; Yang et al., 2013). As the Dulong people have adapted to their living environment, they have a wealth of TBK associated with bamboo (Long et al., 1999), running through all aspects of life, e.g., collecting bamboo shoots for food, using bamboo leaves to treat diseases, weaving bamboo items and tools, and using bamboo in clothing, construction, transportation, and rituals (Du & Chen, 2016, 2019a, 2019b).

With rapid economic development and drastic societal changes, the TBK associated with bamboo, on which generations have depended, is disappearing at an alarming rate. If this TBK is not investigated and recorded, it may disappear rapidly, resulting in a significant and irreversible loss (Luo et al., 2019). However, research on bamboo and associated TBK in the Dulong community is still limited. With the completion of the Dulongjiang Tunnel for vehicles and other economic development efforts, all Dulong

people have shaken off poverty. The lives of the Dulong people are changing at an unprecedented rate (Cheng et al., 2020). Ethnoecological research on bamboo and their TBK in the Dulong people is urgently required. The purpose of this study was to record the TBK related to bamboo, identify the most influential bamboo species used by the Dulong people, explore the folk identification and management of bamboo species, and analyze the benefits and challenges of TBK related to bamboo in the Dulongjiang region.

2. Material and methods

2.1. Study area

Dulongjiang Township, the only settlement of the Dulong people in China, is west of Gongshan Dulong and Nu Autonomous County, Nujiang Lisu Autonomous Prefecture, Yunnan Province, China (Figure 1). Dulongjiang Township (27°40'–28°50' N, 97°45'–98°30' E) is adjacent to the Bingzhongluo and Cikai townships in the east, Chayu County of Tibet Autonomous Region to the north and Kachin State of Myanmar to the west and south. Dulongjiang Township has a typical alpine gorge landform with a large altitude gradient of 1172–4862 m (Cheng et al., 2020). The Dulongjiang region has been isolated for a long time and continues to be even today from December to June due to winter weather conditions. It is still the most remote, poor, backward, and closed area. The Dulongjiang region has a vertical and diverse climate and abundant rains, with an average annual rainfall of 3670 mm. It is located within a small area with the highest rainfall in the country (Cheng et al., 2022b). Dulongjiang Township is one of the core areas of the Gaoligongshan National Nature Reserve and the Three Rivers Parallel World Natural Heritage Sites. The township harbors dense primary forests. It is one of the places with the highest biodiversity in China, with 275 species in 41 families of ferns and 2003 species in 158 families of seed plants in the limited area (Cheng et al., 2022a).

Dulong is one of the fifty-five minority groups in China and has the smallest population in Yunnan Province. The Dulong people in Dulongjiang Township account for 99% of the total population (6,930 people only). Most people speak Dulong, and only young people can speak Mandarin Chinese. The incomes of these local people

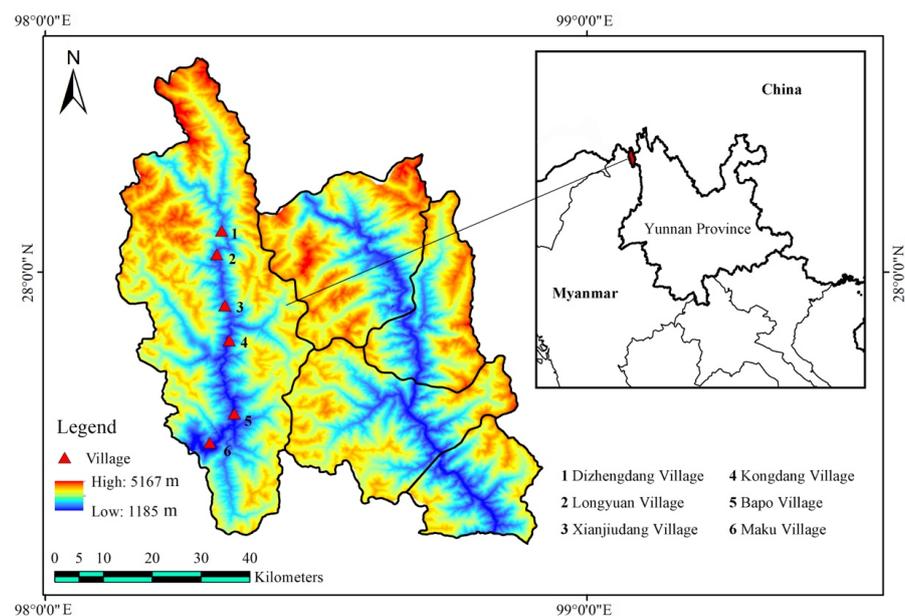


Figure 1 The study area: Dulongjiang Township, Gongshan County, Yunnan Province, China.

are exceptionally inadequate, and the primary sources are spices and herbs collected from the forests.

2.2. Field survey and data collection

Based on the local chronicles, maps, and flora, a preliminary understanding of the topography, climatic conditions, and vegetation of the Dulongjiang area and the history, customs, religious beliefs, and social culture of the Dulong people preceded the ethnobotanical investigation, which helped in choosing an appropriate site and time for the survey.

Four field surveys were conducted from 2019 to 2020, and the investigation sites included six villages. First, 30 participants were selected using the snowball method. Most of the informants were or had been engaged in bamboo weaving. Second, the informants were interviewed using participatory observation, a free list, and semi-structured interviews. The information obtained in the interview mainly included basic information (nationality, gender, age, education level, and occupation) and detailed information on the bamboo used by the informant, including the local names and usage. In addition, we showed bamboo pictures prepared in advance to the informant to establish the accuracy of the recorded information. Data were recorded and analyzed using different quantitative indices.

2.3. Species identification

During the field investigation, researchers, accompanied by Dulong guides, conducted field trips to obtain plant specimens and observed the habitat characteristics, resource status, and different bamboo forest types. Additional information about the ecological and biological traits of bamboo during various seasons was provided by Dulong guides. Some bamboo species are distributed at altitudes that are too high to reach. We determined the correctness of species identification by consulting local people, literature, databases, and related bamboo experts for these species.

For the identification of plants, the voucher specimens were studied and compared with reference books (*Flora Reipublicae Popularis Sinicae*, *Flora of China*, *Flora of Yunnan*, *Flora of Dulongjiang Region*) and electronic online resources (<http://www.iplant.cn/> and <http://www.theplantlist.org/>). The nomenclature of all vascular plants follows *Flora of China*. Prof. Chunlin Long identified all plant species, and voucher specimens were deposited in the herbarium of the Minzu University of China in Beijing.

2.4. Quantitative indices

The use value (UV) and the relative frequency of citations (RFC) were used to evaluate and compare the importance of bamboo plants used by the Dulong people. To quantify the frequency of use of certain species, we calculated their utilization frequency using the following formula:

$$RFC = \frac{FC}{N}$$

This parameter refers to the ratio of the number of respondents who mention a particular bamboo plant (frequency of citation, FC) to the total number of respondents participating in the survey (N). The larger the RFC, the more important and valuable the bamboo plants in the area. The importance of each bamboo plant was indicated by its FC value, which allowed all bamboo plants mentioned in the survey to be listed in the order of importance (Vitalini et al., 2013).

The UV was used to measure the relative importance of the locally used species. The UV is calculated as follows:

$$UV = \sum \frac{U_i}{n}$$

where U_i is the number of uses mentioned by each informant for a given species, and n refers to the total number of informants. The higher the UV, the higher the utilization value of the species. Plants are often used in research and are relatively important (Tardio & Pardo-de-Santayana, 2008).

3. Results

3.1. Diversity of bamboo species

Through ethnoecological investigations, 12 bamboo species belonging to seven genera used by the Dulong people were recorded. The most dominant genus was *Fargesia*, followed by *Cephalostachyum*, and the remaining genera contained only one species in each genus. Botanical, ethnobotanical, and ethnoecological information about these bamboo species, including scientific names, vernacular names, genus, altitude, RFC, and UV, are listed in Table 1.

Table 1 Inventory of bamboo used by the Dulong people.

Scientific name	Genus	Local name	Altitude (m)	RFC	UV
<i>Cephalostachyum scandens</i> Bor.	<i>Cephalostachyum</i>	q ri dan	1600	0.59	0.62
<i>Cephalostachyum virulentum</i> Y. M. Yang & Fan Du	<i>Cephalostachyum</i>	ri leng	1320–2000	0.7	1.14
<i>Chimonobambusa armata</i> (Gamble) Hsueh & T. P. Yi	<i>Chimonobambusa</i>	qu	1500–2000	0.62	1.38
<i>Dendrocalamus fugongensis</i> Hsueh & D. Z. Li	<i>Dendrocalamus</i>	de wa	1200–1800	0.81	2.76
<i>Fargesia declivis</i> T. P. Yi	<i>Fargesia</i>	ri geng	2450	0.41	0.57
<i>Fargesia pleniculmis</i> (Hand.-Mazz.) T. P. Yi	<i>Fargesia</i>	deng ma	2500–3000	0.76	2.41
<i>Fargesia sagittatinea</i> T. P. Yi	<i>Fargesia</i>	wa	2450–2900	0.24	0.38
<i>Fargesia praecipua</i> T. P. Yi	<i>Fargesia</i>	si wen, si rang	1850–2600	0.51	0.95
<i>Fargesia melanostachys</i> (Hand.-Mazz.) T. P. Yi	<i>Fargesia</i>	de ma	3000–3500	0.38	0.46
<i>Neomicrocalamus prainii</i> (Gamble) Keng f.	<i>Neomicrocalamus</i>	pi er	1360–1500	0.19	0.19
<i>Phyllostachys sulphurea</i> (Carrière) Rivière & C. Rivière	<i>Phyllostachys</i>	Gan, ri meng	1680	0.86	3.92
<i>Yushania farcticaulis</i> T. P. Yi	<i>Yushania</i>	si man	1920–2800	0.24	0.27

RFC: Relative frequency of citations; UV: Use value.

3.2. Diversity of traditional knowledge of bamboo species

The Dulong people used bamboo species in seven aspects: food, bamboo weaving, clothes, construction, transportation, medicinal purposes, and hunting and fishing tools (Table 2). Eleven bamboo species can be used for food, followed by bamboo weaving with eight species, and seven bamboo species can be used for hunting and fishing purposes. Only two types of bamboo are used for medicinal purposes. Among the 12 bamboo species used by the Dulong people, *Fargesia pleniculmis* has the most uses, followed by *Phyllostachys sulphurea* with six usages, *Dendrocalamus fugongensis* and *Fargesia praecipua* with 5 usages each, and the least used bamboo species are *Yushania farcticaulis* and *Neomicrocalamus prainii*, which have only one use each (Figure 2).

3.2.1. Clothes

The Dulong blanket is representative of the Dulong people. Women blend cotton threads of different colors into colorful blankets using traditional hand-weaving methods. At least five bamboo species are required to weave a Dulong blanket (Figure 3A, B). *Dendrocalamus fugongensis* generally is used to push the yarn to save labor because the bamboo pole is large. *Fargesia pleniculmis* and *F. praecipua* are used to clamp the cotton yarn because the bamboo pole is almost solid. *Cephalostachyum scandens* is used to enwind the cotton yarn because the internode is relatively long, and there is no obstruction by the bamboo joints. *Fargesia declivis* is used to divide the yarn. Some women will put a few stones in the bamboo pole, and there will be a ticking sound when weaving to relieve boredom.

3.2.2. Food

Wild edible plants play a critical role in maintaining food security and micronutrient diversity for local people in remote areas (Kang et al., 2012; Kazanci et al., 2021; Łuczaj,

Table 2 Indigenous uses of bamboo in the Dulongjiang area.

Usage	English name	Local name	Materials	Function	Figure
Clothes	Dulong blanket		<i>D. fugongensis</i> , <i>F. pleniculmis</i> , <i>F. praecipua</i> , <i>Ce. virulentum</i> , <i>Ce. scandens</i> , <i>Y. farcticaulis</i>	Weaving traditional costumes of Dulong people	Figure 3A–3B
Food	Bamboo shoots	Ri meng	<i>P. sulphurea</i> , <i>Chimonobambusa armata</i> , <i>D. fugongensis</i> , <i>Fargesia</i> , <i>Ce. scandens</i> , <i>Ce. virulentum</i> , <i>N. prainii</i>	Bamboo shoots, edible	Figure 3C–3D
Construction	Bedroom	Gong le de	<i>P. sulphurea</i> , <i>D. fugongensis</i> , <i>F. pleniculmis</i> , <i>F. praecipua</i>	House used to live	Figure 3E
	granary	Beng mer	<i>P. sulphurea</i> , <i>F. pleniculmis</i> , <i>F. praecipua</i>	House used to store food	Figure 3F
	Labor room	Beng ra	<i>P. sulphurea</i> , <i>F. pleniculmis</i> , <i>F. praecipua</i>	A house used to rest during work	Figure 3G
	Fence		<i>Ch. armata</i>	Prevent animals from entering the courtyard	Figure 3K
	Pigpen	Wa duo	<i>P. sulphurea</i> , <i>F. pleniculmis</i> , <i>F. praecipua</i>	A tool for raising pigs	
	Beehive		<i>P. sulphurea</i> , <i>Ch. armata</i> , <i>D. fugongensis</i> , <i>F. pleniculmis</i> , <i>F. praecipua</i>	A sheltered place to avoid rain in the beehive	
Transportation	Ziptreck		<i>F. pleniculmis</i>	A river crossing tool	Figure 3L
	Bamboo bridge		<i>P. sulphurea</i> , <i>D. fugongensis</i>	A river crossing tool	Figure 3J
Medicine	Bamboo fungus	Deng ma mer he	<i>F. pleniculmis</i>	A fungus that parasitizes on <i>F. sinensis</i>	Figure 3H–3I
	Bamboo leaves	Gan	<i>P. sulphurea</i>	The leaves of <i>P. sulphurea</i> were boiled in water, and taken orally to treat cough	
Bamboo weaving	Pack basket	Deng rong, He mei, Bai guo, Gong ying	<i>P. sulphurea</i> , <i>F. pleniculmis</i> , <i>F. praecipua</i> , <i>D. fugongensis</i>	A tool for collecting fuelwood, food, and feed.	Figure 4A
	Sundries basket	Ba du		Basket for sundries	Figure 4B
	Baking basket	Bra qi		Baskets of grain or fuelwood that need to be dried	Figure 4C
	Food basket	Brong gai		Baskets for corn and other grains	Figure 4D
	Fruit basket Snack basket	Grong Gu qi		Basket for fruit Basket for snacks	Figure 4F Figure 4G

Continued on next page

Table 2 Continued.

Usage	English name	Local name	Materials	Function	Figure
	Fish basket	Xia bi		Basket used for fishing	Figure 4H
	Labour basket			Basket used in work	Figure 4I
	Bamboo spade	Bra		Tools for drying grain	Figure 4K
	Needlework basket	Deng gong	<i>Ce. virulentum</i>	Basket for needle and thread	Figure 4E
	Square basket		<i>Ce. virulentum</i>	A square basket for decorations	Figure 4J
	Bamboo hat		<i>P. sulphurea</i>	Tools for shelter from rain and sun	Figure 4L
	Bamboo besom		<i>P. sulphurea, Fargesia</i>	Cleaning tools	Figure 4M
	Bamboo cup		<i>D. fugongensis</i>	Tools used to hold water and wine	Figure 4N
	Bamboo pipe		<i>P. sulphurea</i>	Made from the enlarged rhizomes of bamboo	Figure 4O
	Bamboo spoon		<i>P. sulphurea</i>	Soup tools	Figure 4P
	Tea bucket		<i>D. fugongensis</i>	Tools used to make butter tea	Figure 4Q
	Bamboo flute		<i>P. sulphurea</i>	A musical instrument	Figure 4R
	Chicken coop	Ga gong	<i>P. sulphurea</i>	A tool for raising chickens	Figure 4S
Fishing and hunting	Fishing rod	Qiu	<i>P. sulphurea, Fargesia, Ce. virulentum</i>	A tool for active fishing	
	Fish trap	Sang	<i>P. sulphurea, F. pleniculmis, F. praecipua</i>	A passive fishing tool, there are big and small	Figure 4T–4V
	Crossbow		<i>Fargesia, Ce. virulentum</i>	Used to hunt large animals with poisonous plant (<i>Aconitum ouvrardianum</i>)	Figure 4W–4X
	Animal trap	Gou	<i>P. sulphurea, F. pleniculmis, F. praecipua</i>	Used to hunt small animals	Figure 4Y

2012, Łuczaj et al., 2012). In May 2020, many tourists were stranded in Dulongjiang Township because of heavily rain-disrupted roads. Local people keep these tourists from starving by digging for wild edible plants, such as bamboo shoots. Bamboo shoots are a source of wild vegetables for many ethnic minorities in Southwest China (Yang et al., 2004a). Our previous research found that the Dulong people eat as many as eight kinds of bamboo daily, and bamboo shoots can also be used as fodder for livestock (Cheng et al., 2022b) (Figure 3C, D). In the Dulongjiang area, except for *Y. farcticaulis*, all species of bamboo shoots are edible. Dulong people have a unique way of eating bamboo shoots, which are usually fried or boiled. When bamboo shoots are collected in large quantities, they are pickled or dried into sour or dried bamboo shoots, respectively.

3.2.3. Construction

The architecture of the Dulong people is distinctive. Adapting to local conditions, they use plant materials from the local environment to build houses appropriate for different altitudes, such as houses built using corrugated wooden blocks or sheets and bamboo strip houses (Figure 3E–G). In addition to building homes, the Dulong people use bamboo for fences. The joints of *Chimonobambusa armata* are covered with thorns and can be used to create barriers to prevent animals from entering yards or farmlands.

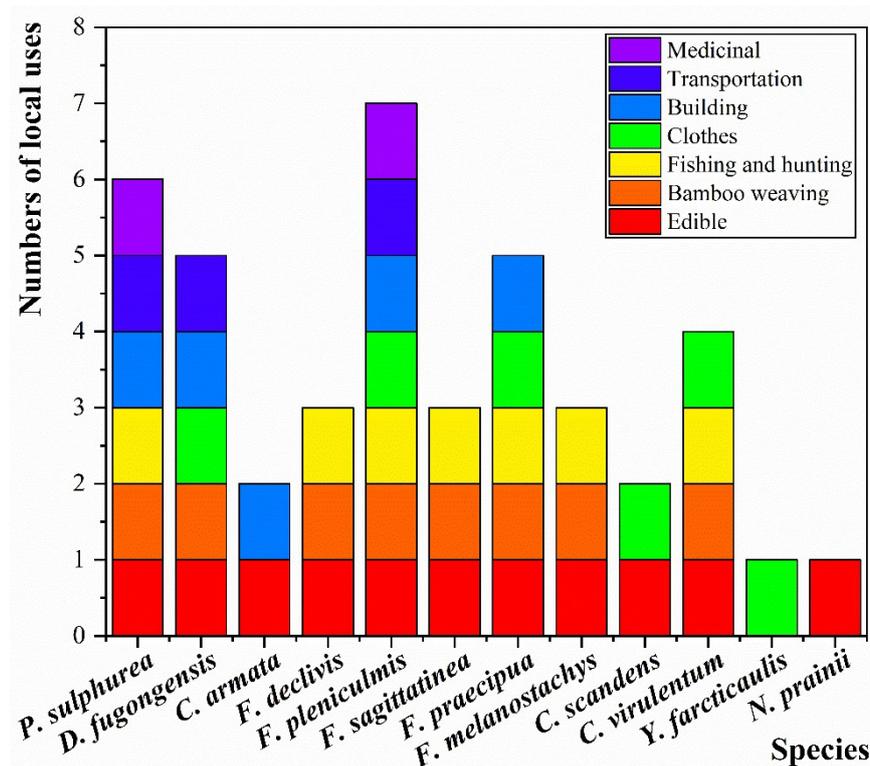


Figure 2 Different uses of bamboo species.

3.2.4. Transportation

The Dulongjiang area is a typical alpine gorge landform with extremely inadequate road conditions. The Dulong people use bamboo to build ziptrecks and bridges to ensure travel. Due to its toughness, *F. pleniculmis* is the only bamboo source used for making ziptrecks (Figure 3J–L).

3.2.5. Medicinal purposes

Dulong people have lived in harsh environmental conditions for a long time and have gradually accumulated some traditional knowledge of medicine, using different bamboo species to treat diseases. For example, *P. sulphurea* leaves soaked in water are used to treat colds, and the bamboo fungus on *F. pleniculmis* is soaked in liquor to treat tonsillitis (Figure 3H, I).

3.2.6. bamboo weaving

Dulong people have various bamboo tools, such as baskets, hats, brooms, cups, pipes, spoons, tea buckets, and flutes (Figure 4). These tools, made of different bamboo materials, have diverse functions and names. In particular, there are as many as ten varieties of bamboo baskets. When a guest enters the house of the Dulong people, the host may entertain the guest with cornmeal in a snack basket (“Gu qi”, Figure 4G) or a fruit basket (“Grong”, Figure 4F) packed with fruits. A Dulong man may carry a fish basket (“Xia bi”, Figure 4H) when fishing. The women may use needlework baskets (“Deng gong”, Figure 4E) while shopping. These woven bamboo products are indispensable in daily life.

3.2.7. Hunting and fishing methods

Fishing and hunting have traditionally been critical livelihoods for the Dulong people (Du & Chen, 2019b). Dulong people have mastered various fishing methods, including active strategies, such as using fishing rods, and passive methods, such as



Figure 3 Bamboo species used by the Dulong people in daily life. (A–B) Bamboo species used in the process of Dulong blanket weaving: *Fargesia pleniculmis* (1), *Dendrocalamus fugongensis* (2), *Cephalostachyum scandens* (3), *Fargesia praecipua* (4), and *Fargesia declivis* (5); (C) bamboo shoot of *F. pleniculmis*; (D) bamboo shoot of *D. fugongensis*; (E) bedroom; (F) granary; (G) labor room; (H–I) bamboo fungus – *Hypocrella bambusae*; (J) bamboo bridge; (K) fence; and (L) ziptrack.

fish traps (Figure 4T–V). The rich biodiversity in the Dulongjiang area provides a broad opportunity for Dulong people to hunt (Du & Chen, 2019a). Hunting methods included the use of crossbows and traps (Figure 4Y). Bamboo arrows indicate *Fargesia* species. For large animals, such as bears and tigers, poisonous arrows made from *Cephalostachyum virulentum* are needed (Figure 4W, X).

Due to its unique geographical location and alpine and gorge landforms, the Dulongjiang area has abundant bamboo plant resources (Du et al., 2013; Yang et al., 2013). Dulong people have accumulated a wealth of traditional knowledge associated with bamboo species through long-term interactions with the living environment (Table 2), demonstrating that the production, life, culture, and other aspects of the Dulong people are inseparable from bamboo.

3.3. Folk classification of bamboo species

The Dulong people know about the altitude, morphology, and purpose of surrounding bamboo species. They can quickly find bamboo species according to their specific distribution, growth altitude, and morphological characteristics.

The altitude of the bamboo plant recorded in the field survey was the same as that provided by the informant (Table 1). As shown in Figure 2, *D. fugongensis* and *N. prainii*



Figure 4 Bamboo weavings and tools used by the Dulong people. (A) Pack basket; (B) sundries basket; (C) baking basket; (D) food basket; (E) fruit basket; (F) snack basket; (G) fish basket; (H) labor basket; (I) bamboo spade; (J) needlework basket; (K) square basket; (L) bamboo hat; (M) bamboo besom; (N) bamboo cup; (O) bamboo pipe; (P) bamboo spoon; (Q) tea bucket; (R) bamboo flute; (S) chicken coop; (T–V) fish trap; (W) bamboo quiver; (X) bamboo arrow; and (Y) animal trap.

have the lowest altitudes, i.e., below 1500 m, and are close to the Dulong River, whereas some species, such as *P. sulphurea* and *Ch. armata*, are usually between 1500 and 2000 m, near the houses of the Dulong people. Solid bamboo varieties, including *Fargesia* and *Y. farcticaulis*, for making crossbow arrows are distributed at the highest altitude, i.e., above 2000 m, and a few only exist on snowcapped mountains (Figure 5).

Bamboo species have different morphological characteristics. Adapting to and thoroughly using these characteristics, the Dulong people have developed various specific uses for diverse bamboo species. The Dulong people care about whether the bamboo is solid or poisonous, whether the bamboo split is pliable, and whether the length of the bamboo internodes is suitable for processing. For example, *Fargesia* species have a hard texture and are the best material for making crossbow arrows for hunting purposes. *Cephalostachyum virulentum* is toxic and is used mainly for fishing and hunting, and *Ch. armata* has thorns on bamboo nodes and is appropriate for making fences. The bamboo splits of *P. sulphurea*, *D. fugongensis*, and *F. pleniculmis* are pliable and suitable for weaving. The length of *Ce. scandens* internodes is up to 120 cm, appropriate for spinning. Whether the bamboo shoots are edible and their characteristics and taste are also important for the Dulong people to identify the uses of bamboo species. For example, *Y. farcticaulis* shoots are not edible, *Ch. armata* shoots are the

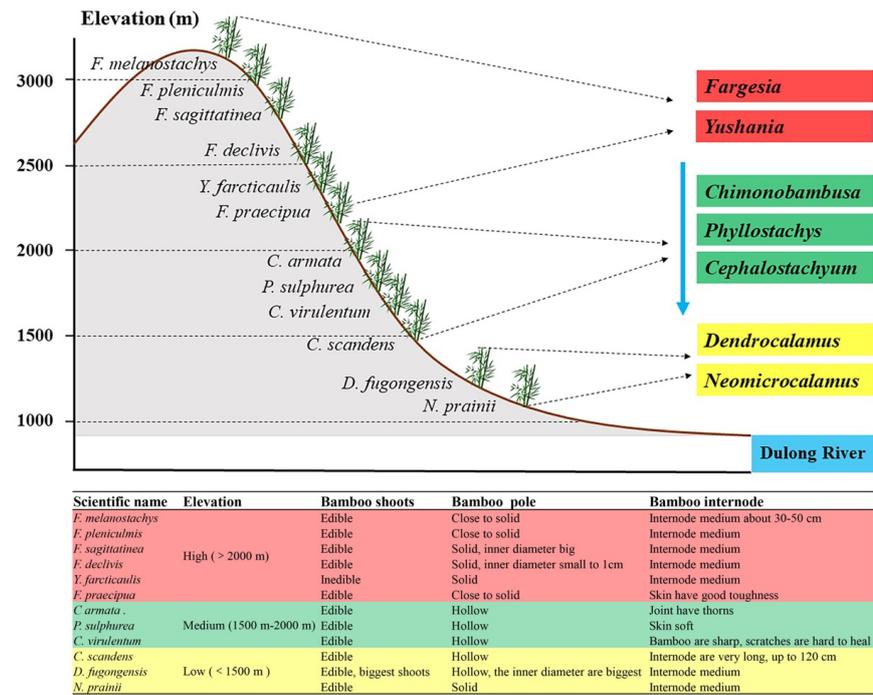


Figure 5 The basis for Dulong people to classify bamboo species.

most delicious, *D. fugongensis* shoots are the largest, and those of *Fargesia sagittatinea* have thorns (Figure 5).

The naming of bamboo species by the Dulong people also reflects the characteristics of their shape, e.g., “de” means big, “si” means solid, and “ri” means internode. Similarly, “de wa” refers to larger bamboo, “si wen” refers to solid bamboo, and “ri leng” refers to long internode bamboo (Table 1). Although the classification of bamboo by the Dulong people differs from scientific classification, the method has great significance in terms of practicability and accuracy for the Dulongjiang area (Wang & Pu, 2003). Folk taxonomy can make it easier for local people to participate in biodiversity conservation, compensate for the insufficiency of traditional classification work, and promote the rapid assessment of species diversity in local areas (Addi et al., 2022). Second, folk taxonomy helps conserve biodiversity in local communities (Wang et al., 2019). Traditional knowledge related to folk taxonomy is the knowledge accumulated by the local community and surrounding creatures in long-term interactions. Most of these are distinguished based on form, color, taste, time, habitat, purpose, habits, emotion, culture, and other bases for identifying organisms. These characteristics could provide insights into the protection of these species.

3.4. Most popular bamboo species

The RFC reflects the frequency of species reported in a specific area. The larger the RFC, the more the number of times the plant is mentioned and the higher its inferred value and importance in the corresponding region (Bano et al., 2014). The RFC values of all bamboo species ranged from 0.14–0.86, among which the highest was for *P. sulphurea*, followed by *D. fugongensis*, and *F. pleniculmis*, at 0.86, 0.81, and 0.76, respectively.

UV radiation reflects the relative importance of certain plants in a particular area (Zhang et al., 2020). The UV values of all bamboo species ranged from 0.14 to 3.92, among which the highest value was *P. sulphurea* (3.92), followed by *D. fugongensis* (2.76) and *F. pleniculmis* (2.41).

As indicated by their relatively high RFC and UV values, *P. sulphurea*, *D. fugongensis*, and *F. pleniculmis* were the most popular and useful species (Figure 6). These three types of bamboo are abundant and easy to obtain in the Dulongjiang area (Cheng

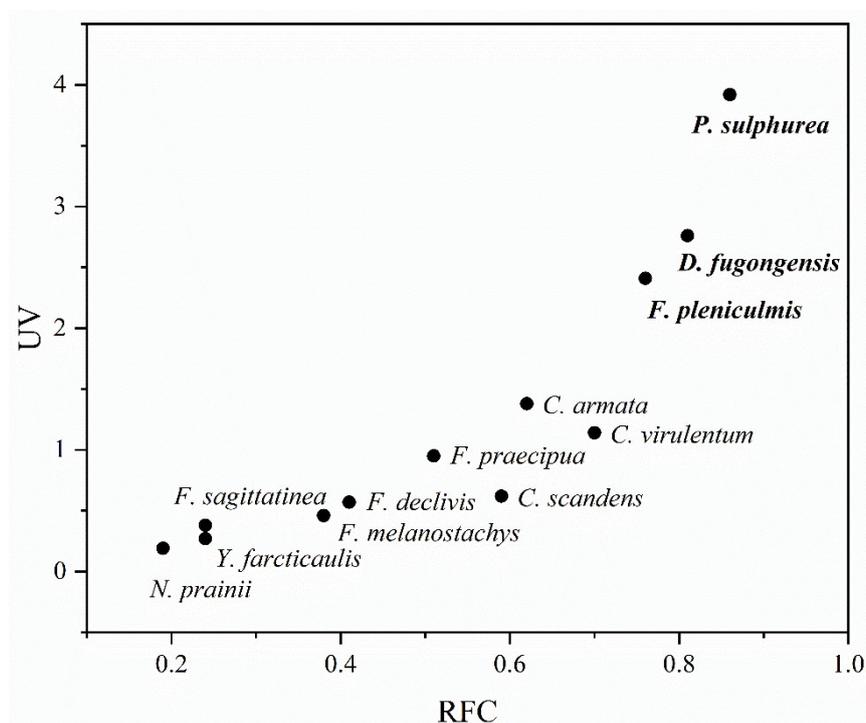


Figure 6 The RFC and UV values of different bamboo species.

et al., 2020). It can be considered the preferred bamboo species and material for the future development of bamboo shoots, bamboo materials, and bamboo weaving tools. The three kinds of bamboo plants have a wide range of uses and can be used to develop products related to these bamboo species, which play an important role in helping local people get rid of poverty, become rich, and reduce their dependence on forests.

3.5. Traditional management of bamboos

The Dulong people traditionally cultivated and managed bamboo around their homegardens and villages to obtain bamboo material more conveniently and for ornamental purposes. Some farmers grow bamboo around their homegardens and farmlands to form natural fences to prevent the destruction of crops. These practices meet the needs of daily life and goods production and increase economic income. It is also a traditional knowledge system that promotes conservation through utilization and is of special significance for the conservation of bamboo genetic resources.

Slash-and-burn agriculture was the main mode of production for the Dulong people before the 1970s. It is still practiced on a small scale in the Dulongjiang region. Slash-and-burn cultivation is a land-use type that involves burning forests and clearing them for planting (Long et al., 1999). The slash-and-burn land from bamboo forests is an important component of the Dulongjiang area. People rely on fertilizers provided by bamboo to ensure production. The Dulong people are very good at managing bamboo forests and have gained rich production experience during long-term slash-and-burn cultivation. They have mastered the knowledge of the terrain, soil, seasons, crop properties, and slash-and-burn skills of bamboo forests and can identify bamboo forests suitable for cultivation. Different types of bamboo forests are used for different types of slash-and-burn land at different times. According to the type of bamboo, these lands can be divided into *P. sulphurea* slash-and-burn land, *Ch. armata* slash-and-burn land, *F. pleniculmis* slash-and-burn land, and *F. praecipua* slash-and-burn land. The Dulong people grow bamboo, together with corn and bean crops in rotation to form an agroforestry system, which not only promotes the protection and development of bamboo but also increases the income of the masses.

4. Discussion

4.1. Protection of traditional biological knowledge

With the development of road infrastructure in the Dulongjiang region, the lives of the Dulong people have undergone significant changes. Transitioning from the primitive mode of slash-and-burn cultivation, gathering, fishing, and hunting to recent poverty alleviation, the Dulong people have had no time to adapt (Cheng et al., 2020). With the acceleration of modernization, the TBK of the Dulong people will inevitably be affected to varying degrees (Cheng et al., 2022a). Finding ways and means to remove dross and preserve the essence, make traditional knowledge and modern civilization adaptable, avoid severe damage to the environment in the industrialization and modernization process, resolve the contradiction and realize the harmonious coexistence with nature are critical issues to be discussed.

The bamboo resources in the Dulongjiang area have been threatened mainly because of easier accessibility to the outside world and the more frequent onslaught of modern civilization, and the TBK of bamboo is at risk of loss (Figure 7). With the impact of external culture, an increasing number of tourists and external products have entered the Dulongjiang area. The lifestyle of the Dulong people is changing quietly. Cultural exchanges between ethnic groups will inevitably impact the traditional knowledge of the relatively small Dulong people (Du & Chen, 2019b). Intergenerational discontinuity is also an important reason for the loss of traditional knowledge (Luo et al., 2019). Most traditional knowledge is in the hands of the elderly, while the younger generations of the Dulong people are not very interested in these traditional methods. As the elderly pass away, their traditional knowledge faces the risk of disappearing.

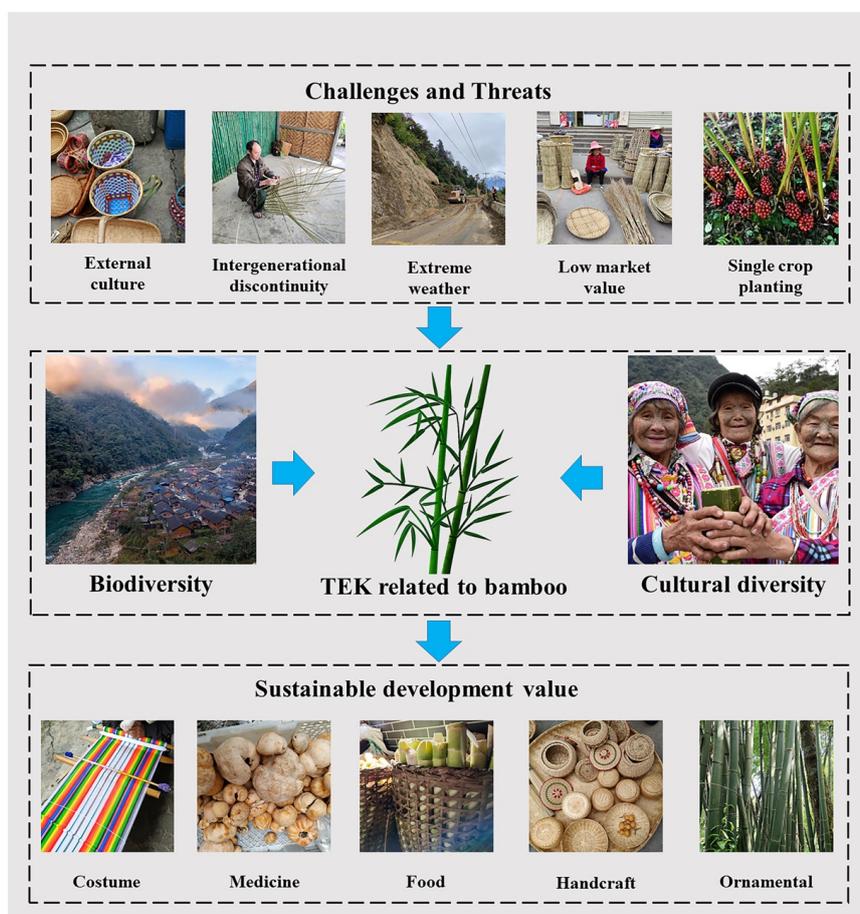


Figure 7 Benefits and challenges of traditional botanical knowledge (TBK) related to bamboo.

To solve these problems, the local government is making efforts to promote bamboo weaving and train technicians so that many young people can master bamboo weaving technology. It is still necessary to pay close attention to the protection of bamboo plants in new economic constructions. Many bamboo plants are distributed on both banks of Dulongjiang Valley and are greatly affected by artificial disturbances, such as road construction, grazing, landslides, and extreme weather. Furthermore, as a native species, bamboo plants have extremely high ornamental value. In recent years, the Dulongjiang area has vigorously developed tourism and many ornamental plants have been introduced on both sides of the road. The application of native bamboo plants in tourism development should be brought into full play.

4.2. Recommendations and prospects

The Dulongjiang area is one of the original bamboo species centers in Southwest China. The resources of bamboo species are rich. As many as 27 species, specifically *P. sulphurea*, *D. fugongensis*, and *Fargesia*, have ample biomass (Geng et al., 2017). Such a high diversity of bamboo species resulted in the rich bamboo culture of the Dulong people (Yang et al., 2004b). The TBK of Dulong people related to bamboo has tremendous value in the developing bamboo industry. Giving full play to plants in production, life, and culture can alleviate the conflict between forest-edge communities and nature reserves, and promote biodiversity conservation in the Dulongjiang area.

The Dulongjiang area was the only settlement among the Dulong people. With the improvement of transportation and other economic activities, the Dulong people have been lifted out of poverty, and their main income has gradually been replaced by tourism and handmade products. In the future, the development of bamboo shoots, bamboo-derived medicine, bamboo weaving tools, handicrafts, and other industries should be a good choice for the Dulong people, which not only have traditional cultural characteristics but can also bring sustainable economic income (Lu et al., 2021). For example, the Dulong people process bamboo shoots to produce fermented and dried bamboo shoots, which are popular in local communities and markets. Bamboo-derived medicine refers to a fungus, *Hypocrella bambusae*, that grows on *F. pleniculmis* and has anti-inflammatory effects. Bamboo weaving tools are of great variety, highly ornamental, and usable. The vigorous development of these industries plays an important role in promoting the sustainable development of the economy in the Dulongjiang area (Figure 7).

Plastic-derived pollution is a global threat that affects nearly every land and freshwater ecosystem globally (Jambeck et al., 2015). Studies have shown that plastics and other non-degradable materials not only cause great harm to the environment but also pose great risks to human health (Borrelle et al., 2020). The use of reproducible materials such as bamboo is considered more environmentally friendly. Bamboo has the characteristics of fast growth, quick maturity, high yield, diverse usage, and environmental protection and is becoming increasingly popular (Boadu et al., 2022). In the future, bamboo may be further developed as an environmentally friendly material with great potential.

In addition, bamboo is of great value for ecological protection and ornamental purposes (Zheng et al., 2021). The Dulongjiang area is the core of the Gaoligongshan National Nature Reserve. It promotes the bamboo culture of the Dulong people to become a symbol of the Dulongjiang area and accelerates the development of tourism. Rich bamboo resources can be exploited to make new contributions to the prosperity of the rural economy, the construction of ecological civilization, and the development of ecological tourism.

5. Conclusion

This study investigated the TBK associated with 12 bamboo species used by the Dulong people. The Dulong people possess rich TBK to recognize bamboo and its ecological properties and use bamboo in life, culture, and goods production. These bamboo species and their traditional knowledge have great potential for conserving local biodiversity and sustainable development. In the future, the development of

industries related to bamboo plants will be encouraged, including edible bamboo shoots, bamboo-derived medicine, and the bamboo weaving industry, in addition to its ecological and cultural functions.

Acknowledgments

We thank Prof. Heng Li from the Kunming Institute of Botany, Chinese Academy of Sciences for her helpful suggestions. We are very grateful to Shiping Yang and Jinxiu Pan in Dulongjiang Township, Yunnan Province, who provided valuable bamboo picture and to members of the Ethnobotanical Laboratory at the Minzu University of China for participating in the field surveys.

Ethics approval and consent to participate

All participants were asked for their free prior informed consent before interviews were conducted.

Consent for publication

Oral informed consent was obtained from all people interviewed and those appeared in Figure 7.

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