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# The Role of Montane Forests for Indigenous Dongba Papermaking in the Naxi Highlands of Northwest Yunnan, China

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China's rapid economic development is influencing cultural practices and natural resource management in indigenous mountain communities throughout the country. Numerous studies have documented loss and change of

cultural practices and environmental degradation in indigenous communities with the expansion of roads, markets, tourism, and other infrastructure development. The present study focuses on papermaking, a socioecological practice that began in China, as a case study to examine the influence of development on cultural practices and natural resource management. The Naxi are an indigenous people who primarily inhabit the mountains of the eastern Himalaya in China's northwest Yunnan province. The Naxi people are unique in that they have the last remaining pictographic writing system in the world. The Naxi pictographic script is customarily learned and mastered by shaman priests known as Dongba (Dto'mba) who transmit their knowledge to their sons. Approximately 300,000 Naxi live in this area. The

pictographic system is transmitted on paper sourced from montane forest resources, primarily *Wisktroemia delavayi*. This cultural tradition almost disappeared during the Cultural Revolution in China during the 1960s and 1970s but has recently seen a revival. Research involved both ethnographic interviews and ecological sampling. Semistructured interviews were conducted with 100 informants between 2002–2011 to understand the management and use of *W. delavayi* for Dongba papermaking and the impact of market integration on papermaking. Sample plots were surveyed for floristic composition and structure in the 3 vegetation types where *W. delavayi* grows. Density, height, diameter, and number of branches of *W. delavayi* plants were recorded within each plot. Ecological importance values were calculated based on relative density, relative dominance, and relative frequency to determine the habitat where *W. delavayi* demonstrates the greatest growth. Additional plots were surveyed to understand the regeneration of *W. delavayi* after the local harvest cycle.

**Keywords:** Naxi; Himalaya; ethnobotany; ethnoecology; papermaking; *Wisktroemia delavayi*; montane forests; China.

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## Introduction

China's rapid economic development is influencing cultural practices and natural resource management in indigenous mountain communities throughout the country (Ahmed et al 2010; Guo et al 2002). Numerous studies have documented loss and change of cultural practices and environmental degradation in indigenous communities with the expansion of roads, markets, tourism, and other infrastructure development (Godoy et al 2005). The present study focuses on papermaking, a socioecological practice that began in China, as a case study to examine the influence of development on cultural practices and natural resource management. The indigenous highland sociolinguistic groups of

southwestern China, including the Naxi (Nakhi), Bai, Dai, Tibetan, and Yi, adapted papermaking that reflected the plant resources of their surroundings. The earliest papers were made from tree and herbaceous plant fibers, including mulberry (*Morus* sp; Moraceae), hemp (*Cannabis* sp; Cannabaceae), and *Wikstroemia* spp (Thymelaeaceae). Expression through drawing and writing on paper became a key mode of transmitting knowledge and culture, particularly for the Naxi, who today have the only remaining pictographic system in the world.

The Naxi are a Burmo-Naxi-Lolo sociolinguistic group within the Tibeto-Burman group of the Sino-Tibetan family (Matisoff 1991) that primarily inhabit the highlands of Lijiang Naxi Autonomous Region in the eastern Himalaya of China's northwest Yunnan. They are one of

China's 55 recognized minority groups. The Naxi settled along the upper reaches of the Jinsha River from northeastern Tibet and Sichuan. Approximately 300,000 Naxi live in this area, which encompasses the region where the Himalayan biodiversity hotspot meets the Mountains of Southwest China biodiversity hotspot (WWF 2009). A strong correlation between biological and cultural diversity has been documented in this region (Stepp et al 2005). The Naxi commercial center of Lijiang is situated along a major regional trade route, the Southwest Silk Road (also known as the Tea Horse Road), and has more than a millennia-old history of interactions with other sociolinguistic groups that travelled between Yunnan, Tibet, and India (Freeman and Ahmed 2011). Naxi monarchs semiautonomously ruled the territory until 1723 when it was nationalized by China.

The Naxi have 2 scripts unique to their language and culture: a syllabic and a pictographic system. The Naxi pictographic script is customarily learned and mastered by shaman priests known as Dongba (Dto'mba), who transmit their knowledge to their sons. The Naxi pictographic system serves a mnemonic function, such as to guide ritual chants of their Bon practice (Rock 1937). The traditional Bon practice is characterized by animist and shamanistic traditions with links to pre-Buddhist and Buddhist Tibetan practice. Naxi scripts are considered to have developed in the context of cultural exchange with Tibetan writing systems, because the Naxi's strong ties with Tibet resulted in similar practices (Michaud 2006). Naxi pictograms are likely to have further developed when the Naxi moved to their present territory because the flora and fauna depicted are found around their current settlements (Rock 1937). The Dongba technique to make paper for documenting their scripts was influenced by the fixed-mold papermaking technique of Tibetan communities and the movable-mold papermaking technique of central China (Li 2003). It is notable for its practice of pouring and laying natural fibers (Fan and Zhang 2009).

Naxi communities customarily used the inner bark of *Wikstroemia delavayi* Lecomte (Thymelaeaceae) and sometimes *Wikstroemia lichiangensis* W.W. Sm. to produce paper for documenting traditional Dongba scripts. *W. delavayi* is distributed across lime rock soils where elevation ranges from 1700 to 3800 m. It is a sun-loving shrub or tree with numerous branches, opposite and obovate leaves, yellowish green flowers, and cylindrical fruit (Qi and Wang 2002). *W. delavayi* and *W. lichiangensis* are regarded to have extraordinary characteristics for papermaking because of their low lignin content (approximately 10%) and slender fibers (Lin et al 2007). Their chemical constituents contain compounds that increase the resistance of the resulting paper from microbial destruction.

Dongba scripts, papermaking practice, and *Wikstroemia* resources have been threatened over the past 6 decades by

the implementation of new policies and development programs. China's Revolution in 1949 led to profound changes in the region, because the state prohibited most religious activities and encouraged exploitation of natural resources. *Wikstroemia* populations declined, and indigenous land management weakened with the state's redistribution of household land as communal resources. Forest degradation resulted as processes linked to the tragedy of the commons took hold. The Great Leap Forward (1958), Minor Autumn-Harvesting Campaign (1958–1960), introduction of the Latin-based phonographic system, market liberalization (from 1986), and logging bans after the Yangtze River flood (1998) further influenced *Wikstroemia* populations and overlooked local practices. Communities directed their efforts away from traditional livelihood practices as they adopted strategies promoted by the state. Dongba papermaking was revitalized with market liberalization and the tourist boom linked to the declaration of Lijiang as a Chinese National Treasure (1986) and United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Site (1997). The first academic exploration and translation of Dongba pictographs was undertaken in the 1930s by Austrian-American explorer Joseph Rock (Rock 1937, 1939, 1963).

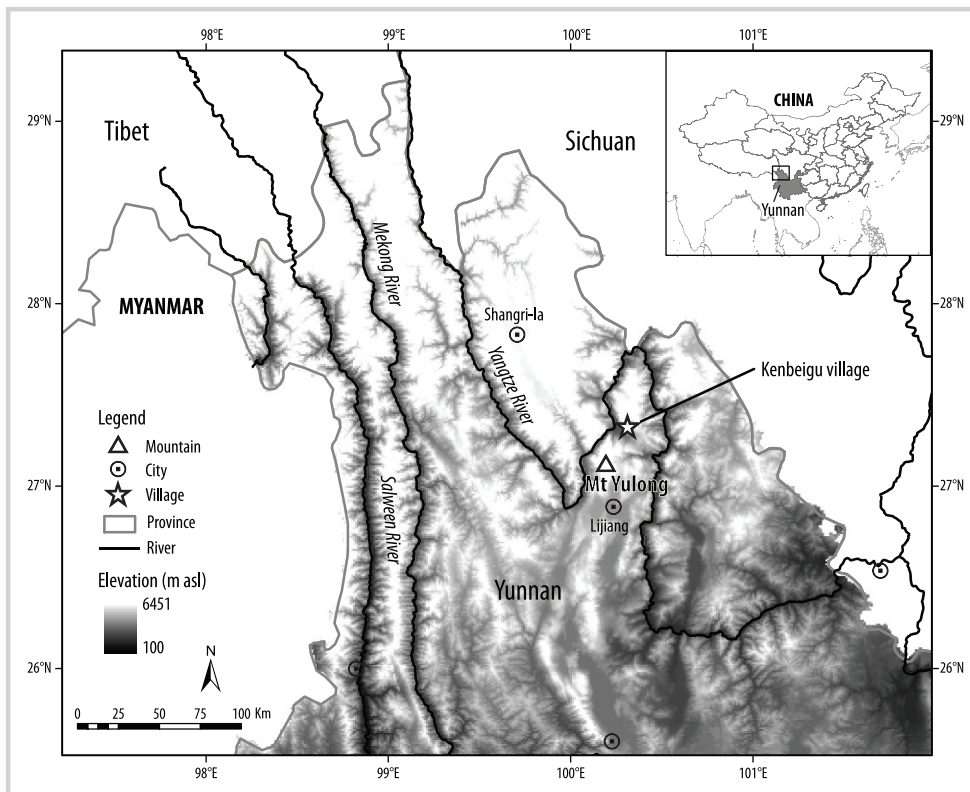
This study seeks to document the persistence and change of Dongba papermaking practices and associated resource management and livelihood. Participant observation, interviews and ecological sampling were conducted in a Naxi highland community in Northwest Yunnan, China. Interviews also were administered with middlemen and vendors in the nearby commercial center of Lijiang to understand drivers of commercialization and implications for sustainability. Research was conducted between 2002 and 2011, a period corresponding to rapid expansion of development, tourism, and natural resource commercialization in Northwest Yunnan. This study builds on previous findings by some of this study's authors (Lixin et al 2007) on the regeneration and use of *W. delavayi* for papermaking. More recent research herein brings insight into the role of development on cultural practices, natural resource management, and livelihoods, and has potential application for designing sustainable management strategies and policies.

## Material and methods

### Study site

Research was conducted in Kenbeigu Village, a highland Naxi community in the Baimai administrative village of Daju Township, Yulong Naxi Autonomous County, Lijiang City, Northwest Yunnan Province (Figure 1). Kenbeigu is situated at 27°18.78'N and 100°18.21'E at an altitude of 2645 m in a temperate montane forest. It was selected as a study site because of its extensive papermaking history with using *W. delavayi*, the presence

**FIGURE 1** Kenbeigu village (27°18.78'N and 100°18.21'E), Northwest Yunnan, China. (Map by authors)



of 2 Dongba priests in the community, and its relatively remote location. *W. delavayi* individuals are distributed in 3 habitat types around the study site at an altitude of approximately 2650 m, including (i) needleleaf forest community dominated by *Pinus yunnanensis* Franch, (ii) a dwarf broadleaf Fagaceae forest community and, (iii) grasslands. The nearest market town is Lijiang, a UNESCO World Heritage Site, located 86 km from Kenbeigu, or 2.5 hours by automobile.

In 2011, 212 Naxi adults (112 men and 100 women) inhabited Kenbeigu in family units of 48 households. Livelihoods are reliant on the surrounding forests and fields for agriculture, wild harvesting, and raising livestock for subsistence and commercial purposes. Particular areas within the community are protected based on spiritual beliefs and customary land use. Households manage a collective total of 3.2 ha of lowland fields and 21.3 ha of highland fields where they grow corn, wheat, white and red beans, soybean, buckwheat, and potato. Income is generated through sale of lima beans, pigs, timber, knives, mushrooms, medicinal plants, and Dongba paper. Younger generations increasingly leave the community for income in the tourism industry of Lijiang.

### Interviews

Semistructured interviews were conducted with 100 informants between 2002 and 2011 to document the

persistence and change of Dongba papermaking practices and associated resource management and livelihood. Questions were asked regarding knowledge of papermaking, knowledge of Dongba religion, harvesting and management practices, socioeconomic status, and household economy and demography. Informants in Kenbeigu village were randomly selected from approximately 40% of households. Informants further included 10 collectors of *W. delavayi*, 25 papermaking middlemen, 15 vendors and 15 Dongba and Dongba scholars in Lijiang.

### Ecological sampling

Six 10 × 10-m sample plots were surveyed for floristic composition and structure in the 3 vegetation types where *W. delavayi* grows, including (i) pine forest ( $n = 2$ ), (ii) dwarf broadleaf forest ( $n = 2$ ), and (iii) grasslands ( $n = 2$ ). Data collection of ecological sampling lasted for 3 months with 4 trips from April 2003, June and December 2004 to January 2005. All sample plots were located between 2639 and 2685 m and 3 and 6 km from the village settlement. Pine forest plots were managed as household forests, whereas the dwarf broadleaf forest and grassland plots were managed as common property land open to all community members. Density, height, diameter, and number of branches of *W. delavayi* plants were recorded within each plot. *W. delavayi* plants were grouped as

seedlings (height, <40 cm), young (height, 44–99 cm), or mature (height, >100 cm) on the basis of their branch size. Five 1 × 1-m quadrats were subsampled within each plot for plant species composition.

Data for plots of the same vegetation type were pooled for analysis. Ecological importance values (IV) were calculated based on relative density, relative dominance, and relative frequency to determine the habitat where *W. delavayi* demonstrates the greatest growth. Tukey–Kramer HSD was performed to compare all mean pairs of vegetation habitats of *W. delavayi* based on height and diameter measurements. Differences with  $P \leq 0.05$  values were considered significant.

## Results and discussion

### Interviews

Mountains are of tremendous cultural, ecological, and spiritual importance to the Naxi. This is noted historically (Rock 1939) and continues to the present day as expressed in interviews with community members. Historically, the papermaker in Kenbeigu village and surrounding Naxi communities was the Dongba priest. Dongba paper was used for religious purposes and carried Naxi phonetic and pictographic scripts. An example of Dongba papermaking dating from the late 1800s that the authors documented during fieldwork in 2011 is presented in Figure 2A. During the early 20th century, papermaking transitioned from an activity intricately connected to ritual and spiritual status to an economic activity relegated to common households. Approximately half of the adults in Kenbeigu adopted papermaking in the 1920s and 1930s to support household livelihood. They produced traditional Dongba paper as a commodity for exchange with grain, tea, salt, cigars, sugar, wine, and other products that were traded on networks of the Southwest Silk Road.

The Chinese Cultural Revolution in 1949 prohibited Bon practices, Dongba papermaking and other local traditions in Kenbeigu and across China. State corps burned Dongba sutras. Cultural restrictions were maintained during China's Collective period (1958–1982), and natural resources came under intense exploitation. *W. delavayi* resources for papermaking particularly came under harvesting pressures during the 1960s and 1970s, when the state encouraged commercial extraction of forest resources by outside logging and forestry enterprises. These enterprises hired migrant workers and disregarded local forest management practices.

After the liberalization policy reforms that ended China's Collective period in 1982, households in Kenbeigu did not publically revitalize their Bon practices nor the traditional role of the Dongba priest. Two Dongba priests lived in the community during the study period, both who did not publicly practice Bon traditions, papermaking, and creation of pictograph scripts. One of Kenbeigu's

Dongba priests passed away in 2004 and the village's last remaining Dongba priest passed away in 2011. However, the practice of papermaking based on traditional Dongba techniques has persisted in Kenbeigu as common members of the community revitalized papermaking at the end of the Collective Period upon entering the cash economy. Once an activity only designated to the spiritually elite Dongba priests, all village households engaged in commercial papermaking during the 1980s and 1990s. These products made their way to markets of Lijiang, surrounding tourist destinations and other urban centers of China. This commercial trend halted in 1998 with the implementation of logging bans after the Yangtze River flood damage and attribution of blame to farmer practices. The state imposed limits for harvesting forest resources, including *W. delavayi*. Households could no longer harvest the same quantities of *W. delavayi*, which subsequently discouraged many households from continuing to participate in the harvesting and processing of papermaking resources.

Dongba papermaking persists in some households in Kenbeigu to the present day. These households mention market opportunities that encourage commodification of traditional cultural practices for tourism as a major reason for continuing the practice. State economic development initiatives have encouraged Lijiang, as a top destination for domestic tourism in China, to create an identity based on displaying and commodifying cultural practices of local indigenous groups, which has resulted in revitalization and commercialization of numerous cultural practices and associated material products that were once deemed sacred and for the spiritually elite. In many cases, Dongba practitioners and papermakers note that this shift has been accompanied by a loss of traditional meaning and symbolism of cultural material and replacement by monetary value. In addition, the Dongba Cultural Institute in Lijiang has served to revitalize local papermaking. Although Dongba no longer participate in the production of most paper commercialized in Lijiang, this paper is still branded and marketed as “Dongba paper.” Commercial Dongba papermaking for the tourist market is demonstrated in Figure 2B. The new commercial “Dongba paper” is made industrially from either *W. delavayi* or commercial pulp paper tree species and processed to appear like traditional Dongba paper. Based on our interviews and surveys of shops that sell Dongba paper, essentialized themes of Naxi culture are printed on it, and it usually does not contain the detailed script and stories of the Dongba (Dto'mba) to guide ritual Bon chants.

Four households in Kenbeigu collected *W. delavayi* for papermaking at the beginning of the study period in 2002 and continued through the end of the study period in 2011. These households produce paper for commercial purposes and no longer use it for ritual or other use in the community. Despite the small prevalence of households

FIGURE 2 (A) Traditional Dongba papermaking. (B) Commercial Dongba papermaking. (Photos by the authors, 2011)



that produce paper in the community, all interviewed households have knowledge of the habitats, types, traditional processing, and use of *W. delavayi* resources. Other than for papermaking, informants in Kenbeigu manage *W. delavayi* resources in their land use schemes for medicine and as a natural pesticide that grows in their home gardens and fields.

Interviews revealed that local classification of *Wikstroemia* corresponds to Western taxonomy. Locals classify the 2 *Wikstroemia* spp used to make Dongba paper into 2 categories based on the altitude where it grows and the climatic condition of the area. They classify *W. delavayi* as *rewaiderl*: “re” means “growing along rivers” or “growing in hot places” in Naxi. *W. lichiangensis* is locally classified as *guowaiderl*: “guo,” means “growing on higher mountain” or “growing in cold places.” Kenbeigu’s locals use *W. delavayi* approximately 90% of the time in papermaking because of its greater distribution around the village compared with *W. lichiangensis*. It also is considered superior to *W.*

*lichiangensis*. Informants do not cultivate *W. delavayi*, but they protect it in their home gardens and fields for its properties to deter pests and herbivory.

Interviews with community members regarding environmental perceptions and *W. delavayi* resource management indicated a strong respect for the environment. Dongba at the study site traditionally promoted natural resource management practices that respected the biophysical environment through chants and scripts. Central to the Bon belief system is that “nature” and “human being” are half-brothers with different mothers. A series of chants, stories, and pictograms illustrate punishments for disrespecting the environment and *Shu*, the Nature God, according to rules and regulations set forth in communities by the Dongba.

An example of the worship of the Nature God in a pictograph script is provided in Figure 3. This was drawn and described by a Dongba interviewed in Lijiang in April 2011. In this script, a family asks a Dongba to host a

**FIGURE 3** Contemporary pictograph script depicting environmental management through worship of the Nature God, created by a Dongba priest in Lijiang, China. (Photo by the authors, 2011)



worship ceremony for the Nature God. The Dongba is illustrated on the upper left corner of the pictogram and chants,

*Do not casually cut trees in the mountains. Do not burn forest in the mountains. Do not shoot the crane and great eagle in the sky. Do not kill leopards and tigers in the mountains. Do not hunt deer and wild yak. Do not shoot the bear and the pheasant in the forest. Do not dig silver in the mountains. Do not take gold from the river. Do not shoot the birds. Do not catch fish at will in the stream. Do not harass wild bee nests. Do not kill snake and frogs in the grass. Otherwise, Nature God will punish human beings.*

The Naxi worship of the Nature God influences local environmental perceptions and management.

Another traditional natural resource management practice that was promoted by Dongba in the study site is the harvesting regulation of *W. delavayi*. This regulation deems that *W. delavayi* individuals be left to rest for 3 years after harvest. Throughout the study period, locals continued to follow the traditional 3-year cycle of shifting collection of *W. delavayi* from household and communal forests to allow branches to regenerate for sustainable use. Previous findings on the management of Dongba papermaking resources support that the 3-year traditional harvesting cycle allows for significant regeneration of *W. delavayi* after 3 years since last harvest (Lixin et al 2007). According to this study, height and diameter values of surveyed *W. delavayi* individuals that were last harvested 3 years ago approach measurements of the baseline comparison plots harvested over 8 years ago. These findings suggest the ecological knowledge of households in Kenbeigu and

serve an important role for sustainable forest management.

According to the traditional harvesting system, mature branches are collected March through May when humidity is suitable to separate the outer layer of *W. delavayi* branches. Informants do not collect *W. delavayi* in July and August, because the high humidity can result in a moldy bark that darkens the paper and makes its fibers more susceptible to tearing. Locals report that *W. delavayi* branches have the best growth during this season and allow branches to grow for future harvests. Similarly, they do not harvest young branches.

Throughout the study period, the 4 households active in *W. delavayi* collection each harvested 400 kg annually from 2000 ha alpine forest surrounding Kenbeigu. They harvested every 2–3 weeks from March to May and once per month or every other month for the remaining of the year. The amount of *W. delavayi* bark that is presently harvested is notably less than quantities harvested during commercial peaks before and after China's Cultural Revolution and Collective period. So high was the requirement demanded of the 2 eastern provinces that, from the 1950s to the 1970s, the Daju marketing cooperative started purchasing *Wikstroemia* bark for the papermaking industry outside the province due to a deficiency in local supply. Total harvested bark stood at 10 to 15 tons per year.

Community elders claim that, before the 1940s, 2000 kg of *W. delavayi* branches were annually harvested after the traditional shifting harvest cycle. Households collected *W. delavayi* approximately 10 times a year and middle-aged people primarily led this activity. After the China's liberalization policy reforms in 1982, *W. delavayi* resources again experienced expanded commercialization. During

this time, all adult household members harvested *W. delavayi* 3 days a week during the harvest season for an annual village harvest of 60,000 kg. The frequency of harvesting *W. delavayi* and number of households involved subsided after the 1998 logging bans.

Households in Kenbeigu that produce paper follow traditional Dongba papermaking practices and use traditional tools. This process starts by peeling the bark off the branches and drying the fresh bark material under the sun. A few members in the community develop skin allergies from contact with the inner bark of *W. delavayi*. The sun-dried materials are soaked for several days until they soften. The xylem and remaining dark layers are removed and rinsed with water. The plant material is further softened through boiling, most often by using *P. yunnanensis* as fuelwood. It is then pulverized with a pestle made of *Quercus* spp and kneaded into balls that are placed in *Pinus* spp frames. Water and hemp and bamboo fibers are mixed with the pulp. The pulp slurry is removed from the frame and dried under the sun on boards. The paper product is smoothened with a stone when it is half dry.

Local producers of paper sell it to middlemen who then sell it to either the Dongba Culture Center in Lijiang or to factories for value-added processing into souvenirs such as books, lanterns, and cards. Products made of traditional Naxi paper, or other counterfeit paper that is branded as “Dongba paper,” have seen increased differentiation beyond traditional sutras, including in books, greeting cards, lanterns, paintings, and bookmarks. Commercially collected *W. delavayi* bark is increasingly sold in Lijiang and other urban centers of Yunnan for the tourist market. The greatest demand for *W. delavayi* bark from Yunnan is by China’s eastern provinces of Jiangxi and Zhejiang that process the bark by using industrial papermaking practices. With the expanded markets for Dongba paper, local households, including members of the younger generation, have started to experiment with paper products. Some younger community members were observed pressing local flowers in the paper pulp during paper processing and experimenting with various traditional and contemporary Naxi and Han Chinese designs.

During the study period, Dongba paper generated greater annual income than other modes of income in Kenbeigu. On average, households reported earning 7000 RMB (US\$ 1100) from paper sales annually. Despite attempts to experiment with processing and papermaking products, locals have not tapped into the income potential of value-added products. In 2011, the price of a piece of Dongba paper in the market was 20 RMB (US\$ 3) and with dried flowers added was 40–60 RMB (US\$ 6–9; approximately 20 cm × 60 cm in size); 60–200 RMB (US\$ 10–30) for paper with script (approximately 20 cm × 60 cm in size); and 200–400 RMB (US\$ 30–60) for paintings and calligraphy products (approximately 20 cm × 60 cm). This compares with market prices in 2002 of 2–

5 RMB (US\$ 0.30–0.75) for a piece of paper, 10–15 RMB (US\$ 1.50–2.25) for paper with script, and 20–40 RMB (US\$ 3–6) for paintings and calligraphy products. In general, prices increased between 200% and 1000% from 2002 to 2011.

Interviews indicated that households are aware of market uncertainties and limitations. They perceive the most notable market threat to their traditional papermaking practices and associated livelihoods to be the false branding and marketing of paper products as “Dongba paper” by commercial enterprises. The majority of the paper products labeled as “Dongba paper” in souvenir handicraft stores in Lijiang are made by using alternative fibers, processes, or both. Oftentimes, the products labeled as “Dongba paper” are created through industrial processes.

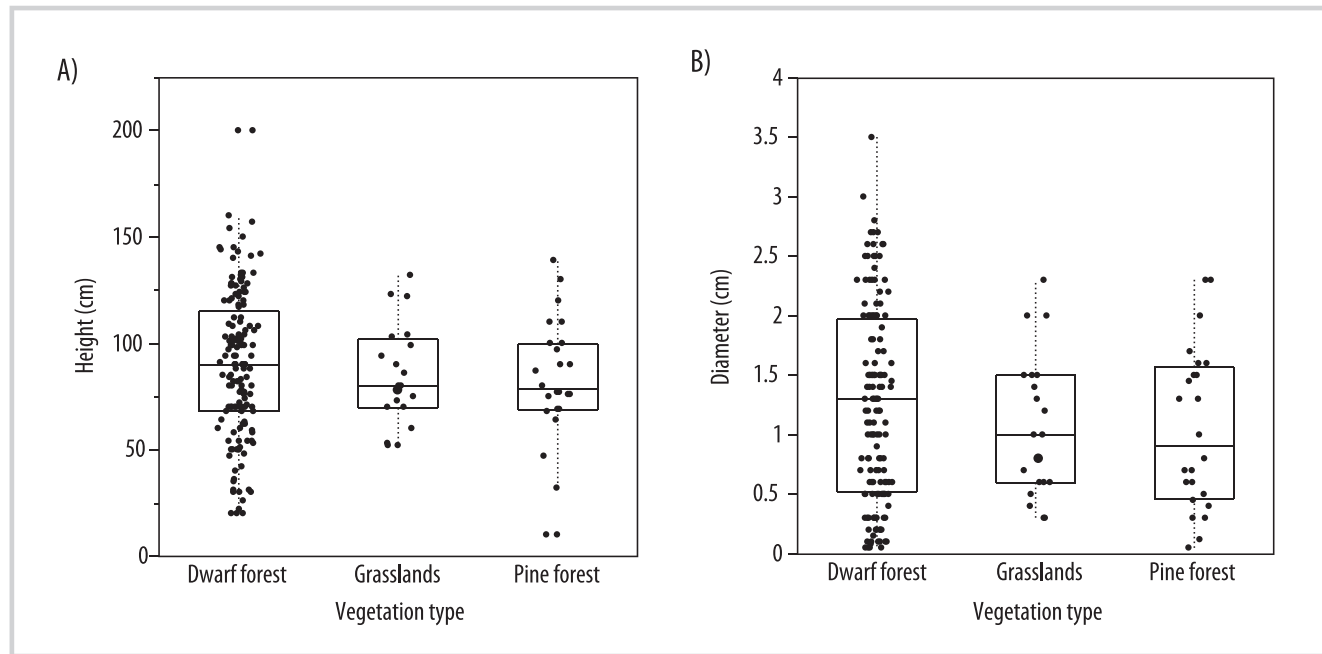
### Ecological sampling

Findings demonstrate the variability of *W. delavayi*’s ecological dominance, depending on the type of vegetation and respective management scheme. Shown in Table S1 (*Supplemental data*; <http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00035.S1>) are the floristic composition and associated IVs of the 3 distinct *W. delavayi* habitats: pine forest, dwarf forest, and grasslands. *W. delavayi* had the highest IVs in the dwarf broadleaf forests managed under a common property scheme, with an average IV of 53.87%. Dwarf forests under common property management schemes had greater plant species diversity in the shrub and grass layers compared with the pine forests managed as household forests. This trend can be explained by households’ decisions to manage their household forest plots for the protection and cultivation of *P. yunnanensis* as a commercial timber species. *W. delavayi* had the lowest IV in the pine forests of *P. yunnanensis* communities, with an average IV of 31.73%.

The presence of *P. yunnanensis* in household forests creates acidic soils and inhibits light and growth for sun-loving *W. delavayi* individuals and other species compared with the dwarf broadleaf forest and grassland plots. Interviews revealed that logging activities in Kenbeigu’s common property forests has decreased the abundance of woody plant species and changed the microclimate from moist to relatively dry, which has been accompanied by the invasion of sun-loving and pioneer shrub and herb species in common property forests. Alternatively, the microclimate remains damp and cool in the household forests that contain greater woody plant species, namely *P. yunnanensis*.

Along with the *W. delavayi*, the shrub layer of dwarf forests were dominated by *Berberis wilsonae* (Berberidaceae), *Campylotropis hirtella* (Papilionaceae), *Cotoneaster buxifolius* (Rosaceae), *Rhododendron delavayi* (Ericaceae), and *Quercus monimotricha* (Fagaceae). The grass layer of dwarf forests was dominated by *Onosma paniculatum* (Boraginaceae), *Leontopodium sinense*

**FIGURE 4** Height (A) and diameter (B) of the *W. delavayi* individuals in each vegetative habitat type: dwarf forest, grasslands, and pine forest. Scattered points represent *W. delavayi* individuals in each vegetation type. Box plots summarize the distribution of height and diameter values (medians, 75th quantile on top and 25th quantile on bottom). No statistical significance was found in values between mean pairs for vegetation type.



(Compositae), *Crepis rigeceus* (Compositae), *Erianthus rufipilus* (Grammineae), *Arthraxon psionocles* (Grammineae), *Cypripedium plectrochilon* (Orchidaceae), *Gentiana lineolata* (Gentianaceae), and *Phtheirospermum tenuisectum* (Sarophulariaceae). The most prevalent species in the shrub layer of the pine forest plots sampled other than *W. delavayi* were *Berberis wilsonae* (Berberidaceae), *Rhododendron delavayi* (Ericaceae) *Coriaria nepalensis* (Coriariaceae), and *Cotoneaster buxifolius* (Rosaceae). The grass layer of pine forests was dominated by *Erianthus rufipilus* (Grammineae), *Arthraxon psionocles* (Grammineae), *Daucus casota* (Umbeliferae) and *Angelica sinensis* (Umbeliferae). The grassland plots were dominated by *Rhododendron delavayi* (Ericaceae), *Berberis wilsonae* (Berberidaceae), *Cotoneaster buxifolius* (Rosaceae), and *Campylotropid polyantha* (Papillionaceae). The composition of the grass layer of grasslands plots consisted of *Erianthus rufipilus* (Grammineae), *Cymbidium goeringii* (Orchidaceae), *Desmodium yunnanensis* (Papillionaceae), and *Sacrophularia lineasis* Saprothulariaceae.

The diameter and height of the *W. delavayi* stand structure in each type of vegetation type are shown in Figure 4. Although dwarf forests have the greatest density of *W. delavayi* individuals, no statistically significant variation was found for diameter and height measurements of *W. delavayi* based on type of vegetative habitat. Each habitat was primarily dominated by mature *W. delavayi* individuals. Pooled data for the 2 pine forest plots sampled had a total of 3 seedlings, 71 young individual, and 71 mature individuals. Grassland plots had no seedlings, 49 young individuals, and 21 mature individuals. Dwarf forests had 29 seedlings, 252 young individuals, and 130 mature individuals.

Interviews indicated that the collection of *W. delavayi* for commercial purposes has resulted in dwarfed height and smaller diameters of populations. Locals recall that *W. delavayi* plants had abundant biomass before state policy encouraged its collection for development purposes. Its height and diameter were directly influenced as it transitioned from a subsistence resource to a commercial product exploited by outside stakeholders who did not follow traditional resource management practices. Informants reported that, before 1949, there were abundant individuals of *W. delavayi* that had diameters of 8 cm and heights near 3 m.

## Conclusions

This study demonstrates that papermaking by using *W. delavayi* resources has transitioned from an activity limited to Dongba priests to a generalized household economic activity. The adoption of traditional papermaking by common households has been driven by commercial opportunities provided by the tourist sector of Lijiang that promotes the display of indigenous cultural practices and commodification of indigenous cultural material. In many cases, the shift of papermaking from a sacred ritual to a livelihood activity has been accompanied by a loss of cultural meaning and symbolism of Dongba paper. Findings show that some Naxi households of Kenbeigu have been entrepreneurial in responding to livelihood opportunities provided by the regional tourist boom by tapping into customary papermaking practices and experimenting with processing and product design. Papermaking has economic development potential in Naxi communities through value-added processing. Consumer programs are needed to

address the issue of “Dongba paper” made through a variety of fibers by using industrial processes.

Although papermaking is no longer heavily associated with spiritual practices, local households continue to follow traditional resource management of *W. delavayi* papermaking resources. This management reflects an overall environmental ethos embedded in the Naxi Bon belief system that was historically promoted through Dongba and their pictograph manuscripts. The decrease and dwarfing of *W. delavayi* populations due to commercial exploitation highlights the need to implement community management practices in forestry schemes. The local practice of following a 3-year harvest cycle and collecting only mature branches serves as a model for sustainable forest management of these resources. *W. delavayi* has promise in the conservation of

mosaics of forest and agricultural land as protection against soil erosion and landslides. It may also have potential as a natural biopesticide for agriculture.

As economic incentives, infrastructure, and reforms drive land use change, Naxi indigenous management practices may provide effective models for natural resource management that link biodiversity and cultural conservation with development. However, because traditional values encoded in papermaking and pictographs are reoriented toward market-based ideologies, communities may risk a breakdown of the environmental management regimes that support sustainable harvesting of *W. delavayi* and other natural resources. As the practice of Dongba papermaking ebbs and flows, additional research is needed to document the unique traditional knowledge encoded in the world's last pictographic writing system.

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## Supplemental Data

**TABLE S1** Floristic composition and associated ecological importance value (IV) of plots sampled in dwarf forests, grasslands, and pine forests with relative density (RD) and relative frequency (RF).

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