Strong ethics and flexible actions, the properties of traditional ecological knowledge (TEK), as key resources for socioecological resilience to the impacts of climate change: a case study of Baojiatun, Yunnan-Guizhou Plateau karst area, southwest China

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ABSTRACT. This paper explores how indigenous people rely on traditional ecological knowledge (TEK) as a means to adapt to climate change. We focus on the observation, interpretation, and adaptation of natural phenomena among farmers from Baojiatun in the karst depression of central Guizhou, where the Han people have settled for more than 600 yr. First, the farmers are culturally rooted in ethics of nature worship and ancestor reverence, forming a community that is sensitive to natural phenomena and governed by local rules and regulations. Second, TEK has a special use in that the indigenous people are not worried about climate change itself because they view their own knowledge system as sufficient to aid adaptation. Third, the properties of TEK are critical resources for socioecological resilience to the impacts of climate change, including a keen observation of phenological change, local indicators for recognizing these changes, and a willingness to abandon certain assumptions as needed in response to changes. This paper suggests that TEK plays an important role in socioecological resilience, because it encourages indigenous people's sensitivity to change and provides an adaptable knowledge system with a strong ecocentric view of nature that can support adjustments and that is flexible enough to accommodate the adjustments needed to respond to changes. The findings of this paper highlight the important role of TEK in fragile ecosystems under global climate change.

Key Words: agro-landscape; change adaptation; climate change; indigenous people; karst; resilience; social-ecological systems; traditional ecological knowledge

INTRODUCTION

Climate Change, Resilience and Traditional Ecological Knowledge

Climate change will amplify existing risks and introduce new risks to natural and human systems, the distribution of which will be uneven across the globe, with farming sectors being highly vulnerable to climate change (Intergovernmental Panel on Climate Change (IPPC) 2014). Karst ecosystems are fragile ecosystems with limited resilience. They are ecologically sensitive and highly responsive to external changes. As a result, rural areas of karst landscapes are greatly affected by global climate change, resulting in extreme weather events (Huang et al. 2020, Zhao et al. 2020), e.g., floods, droughts, and rising river levels, with consequent losses of food sources, wildlife extinction, economic losses, and climate-related disease emergence, which negatively affect and inevitably pose new challenges to livelihoods (IPCC 2014). Are the livelihoods of farmers of the Yunnan-Guizhou Plateau region being affected by climate change, and is traditional ecological knowledge (TEK) helping them respond to such change? This is the research question addressed by this paper. In this paper, we focus on the observations and interpretations of climate change of Baojiatun farmers residing in the karst depressions of central Guizhou (Han populations have settled here for more than 600 yr) and discuss their responses to climate change.

The persistence of a social-ecological system (SES) depends on the amount of disturbance that it can absorb without shifting stability domains, that is, resilience (Holling 1973, Gunderson 2000, Berkes and Jolly 2001, Olsson et al. 2004, Walker et al. 2004, Berkes et al. 2008, Tavares et al. 2015). Resilience is an inherent characteristic of a system supporting adaptation (Holling 1973, van Jaarsveld et al. 2000, Morato et al. 2004). Adaptation involves regulating an SES in response to observed or anticipated environmental change and its impacts (Nelson et al. 2007). Adaptation of an SES either increases its tolerance of change or shortens its adjustment period in response to change (Adger 2000, Folke et al. 2002, Olsson et al. 2004, Cooper and Wheeler 2015). Thus, adaptive capacity is the ability to cope with and/or adapt to disruptive and uncertain socioecological conditions (Olsson et al. 2004, Berkes et al. 2008, Cooper and Wheeler 2015, Zank et al. 2019). Berkes and colleagues (2000) deduced that TEK is a key resource for the adaptive capacity of SES to respond to environmental change. Many studies and applications of TEK in ecological management confirm this assumption, suggesting that TEK plays a role in maintaining biocultural diversity and increasing system resilience and that it serves as a timely and flexible management system derived from the everyday experiences of local people with a sound understanding of local ecosystems and people's roles within them (Berkes et al. 2000, Agnoletti et al. 2015, Kim 2015). However, few of these studies have focused on local people's understanding of ongoing climate change and the measures they are taking to cope with it (Pearce et al. 2015, Armatas et al. 2016, Williams et al. 2020). Williams et al. (2020) argue that without this focus, it is impossible to understand the impacts of climate change and possible solutions to these impacts.

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How vulnerable are indigenous people to global environmental change and globalization in general? What are their relevant adaptation measures, and what are their prospects for coping with change? On the one hand, many scholars have expressed concerns about the resilience of traditional inhabitants in the face of climate change (Salick and Ross 2009, Riva et al. 2013, IPCC 2014). For the poorest and most marginalized communities living in vulnerable areas, whose livelihoods depend on natural resources, global climate change may have disproportionately dramatic effects (Francesca 2016). Berkes (2009) suggests that climate change may challenge traditional knowledge because it is a new and unprecedented phenomenon that indigenous elders have not previously experienced. Similarly, Waugh et al. (2018) argue that traditional knowledge systems cannot be purposefully aware of and responsive to climate change in his documenting of TEK of beluga whales (Delphinapterus leucas) among the Inuvialuit. Bruun and Olwig (2015), through the case study of central Vietnam, question the idea that indigenous people are not “resilient” and “balanced” but rather anthropocentric and thus may exacerbate the risks of climate disasters. On the other hand, although local communities are often highly vulnerable to the negative impacts of climate change, they are also thought to possess specific knowledge that can be used for adaptation (Nakashima et al. 2012, Francesca 2016, Echeverria 2019). Some studies have revealed the capacity for some indigenous or traditional communities to adapt to environmental change and reduce disaster risks (Inaotombi and Mahanta 2018, Carter 2019, Matera 2020), arguing that many indigenous societies have a historical record of adapting to changes in their environment and thus that they can hardly be considered helpless in the face of climate change (Armitage et al. 2011, Nakashima et al. 2012, Boillat and Berkes 2013, Ignatowski and Rosales 2013, Leonard et al. 2013). Traditional ecological knowledge not only helps indigenous people cope with environmental and climate stresses but also contributes to the resilience of SES (Hosen et al. 2019, Williams et al. 2020). Our study therefore focuses on the extent to which traditional communities can rely on TEK to determine their resilience to contemporary climate change. To explore this issue, we examine the TEK of indigenous communities and how their ways of understanding and coping with new changes are related to their TEK.

We drew on the work of Berkes et al. (2000) and Lantz and Turner (2003) to construct a framework used to study TEK concerning climate change. Berkes et al. (2000) proposed the now widely accepted definition of TEK as a collection of knowledge, beliefs, practices, traditions, and customs specifying the relationships between organisms (including humans) and their environments that have evolved through adaptive processes and have been passed down through generations via cultural transmission. According to Berkes (1999) and his paper coauthored with Folke and colleagues (1998), the components of the TEK complex can be seen as management practices based on ecological knowledge, local knowledge of land and animals, and social mechanisms shaping management practices (including land and resource management systems, social institutions, and worldviews). Lantz and Turner (2003:265) introduced and defined the term traditional phenological knowledge (TPK), which refers to the observation of phenological changes in indicator species to signal the seasonal timing of secondary species and knowledge that is embedded in beliefs, myths, rituals, and ceremonies relating to seasonal patterns and conceptions of time and seasonality. The attributes of TPK are specifically expressed by Lantz and Turner (2003) and contribute to the identification of the key features of TEK in relation to phenology, including knowledge and social mechanisms. However, TEK also involves knowledge-based ecological adaptive management practices (Berkes et al. 2000), which are reflected in climate change in the form of meteorological disaster risk mitigation. We therefore argue that a confluent pyramidal analytical framework is appropriate for analyzing TEK related to climate change, which is a system based on a knowledge–practice–belief complex with an inherent causal logic, i.e., worldview is the central motivating factor governing social institutions, management systems, and perceptions of phenomena that guide meteorological disaster risk mitigation (Berkes et al. 2000).

We examine the village of Baojiatun located in the middle of the Guizhou karst depression in China to (1) investigate the traditional ways in which local people recognize and respond to weather events; (2) study the outcomes of traditional ways in which local people observe, interpret, and give meaning to climate change; and (3) study proposed strategies for adapting to climate change based on local experiences of responding to climate change. Our investigation has these three objectives, and our discussion focuses on how local residents rely on TEK to adapt to climate change.

Regional Background and Village History
Karst geology has formed a Tunpu landscape characterized by cone-shaped peaks in the plateau basin, small dams and clear water, and idyllic landscapes with natural beauty and harmony between human and land (UNESCO-WHC 2019). In the area, groundwater resources are more plentiful than surface water resources (Zhang et al. 2006). Rainwater partly converges from peaks to depressions through surface runoff, partly converges into underground fissures and caves through infiltration channels, and exists in the form of groundwater, which flows to form springs when it comes across faults and then flows out through rivers. In Baojiatun (Bao’s village), before the Xing River flows through farming fields, it runs across a fracture zone from west to east, contributing to the river’s abundant groundwater reserves from the faults (Fig. 1).

The Baojiatun area is located 1,260–1,510 m above sea level and has a typical subtropical monsoonal humid climate. Rainfall is unevenly distributed, and the region is prone to droughts, floods, invasions, and hailstorms. According to local historical records published in 2006 (Long et al. 2006), the average temperature in the region is approximately 14°C. The spring season usually runs from late February to late June, when frequent cold air activity and catastrophic weather features such as inversions, droughts, and hail occur. The summer (late June to late August) is characterized by an extreme maximum temperature of 33°C. The autumn runs from late August to late November, when temperatures drop rapidly to as low as 7–8°C. In the winter (November to February), minimum temperatures reach -4°C, and
precipitation is low, with some occurring in the form of freezing rain and snow. The average daily temperature varies greatly in the spring and autumn, and day and nighttime temperatures differ considerably by up to 10–15°C. There are fewer sunny days (127 d on average annually) than cloudy days. Rainfall is relatively abundant with high annual variation (varying from 900–1,900 mm from year to year), and the seasonal distribution is uneven with precipitation from April to September accounting for 80% of annual rainfall. The climate is mild throughout the year with an average relative humidity level of 81%.

As descendants of the Han people in the garrison, the clan society of the Tunpu people advocates Confucian ethics and morals with “filial piety and brotherhood” at their core. In the second year of the Hongwu, Ming Dynasty (1369 AD), Bao Fubao led the Bao family army south to Garrison Puding (now part of Anshun, Guizhou). After a bloody battle between the soldiers and rebels, the rebellion was suppressed. Emperor Zhu Yuanzhang ordered the soldiers to remain in Guizhou to consolidate the southwestern frontier for the sake of long-term peace and stability, “cantoning the frontier in times of war, and cultivating the fields in times of peace.” Bao’s soldiers were awarded a field on which to reside on the frontier with their families, which remained unchanged for generations. A stable clan society formed in Baojiatun, and most of the residents today still have the Bao family name.

According to Baojiatun family records, Baojiatun was originally in a minority area; since the 1370s, it has been inhabited by the Han People who migrated there. Originally populated by Han Chinese army troops stationed in an ethnic minority zone, Baojiatun formed as a typical “cultural island” inhabited by so-called “Old Han Chinese.” In his 1951 Guizhou ethnic survey (Fei 2006), Fei Xiaotong noted, “Many of the Han troops who came in the early years were stationed at various military strongholds called Military Tunpu... The Han who moved here later did not recognize them as Han.” The Old Han People have formed a relatively closed ethnic group. Because of the concentration of their settlements and the strong radiating effect of the powerful position and centripetal force of Han culture, they have been able to retain their own cultural characteristics while exerting varying degrees of influence on neighboring ethnic minorities (Chen 2020). This has strengthened the Old Han People’s pride in their own cultural identity. Therefore, rituals and beliefs that were commonplace in the motherland of Han Chinese have special significance and value in the cultural perseveration of the Baojiatun people. Since the development of the ancestral Bao garrison in Guizhou, a self-sufficient peasant economy has been established. There are approximately 730 households in Baojiatun. The farmland area covers approximately 3.4 km², a watershed of 2,000 km², and the shapes of fields vary according to local water systems with uniform sizes of 1 to 3 mu (approximately 667–2,000 m²). The vast majority of farmers are over 50 yr old, and they make up more than half of the population of Baojiatun. Although Baojiatun is located in the same ecosystem as the surrounding minority villages, which is a karst depression prone to meteorological disasters due to the poor coordination of basic water and soil resources and an uneven distribution of rainfall, Baojiatun has a relatively developed agricultural economy and pleasant agricultural landscape. The farmland is densely populated with waterways with natural twists and turns in the rivers and fields creating configurations of “one dam, one canal, and one piece of field” surrounded by green hills (Fig. 2). Crops are grown once a year, and cultivation occurs in a “long season” and “short season.” The “long season” (April to October) focuses on food crops, such as rice (Oryza sativa) and corn (Zea mays subsp. mays), whereas the “short season” (November to March) focuses on cash crops, such as rapeseed (Brassica napus subsp. napus), sorghum (Sorghum bicolor), and vegetables. Rice and rapeseed are planted in the depressional plain, where the slope is 0–11 degrees, covering continuous arable land. The hills are bell-shaped with relatively steep half-slopes and gently sloping valleys and summits. Dryland crops such as corn and sorghum are grown on the gentle slopes of the low hills with slopes of 11–25 degrees.
METHODOLOGY

Data Collection
The research data are based on three rounds of surveys, and their pathways are shown in Table 1.

We conducted the first round of surveys in 2016. By demonstrating our respect for and interest in their ecological knowledge and sustainable livelihoods, the local residents felt comfortable sharing information with us about their native culture and knowledge.

The second round involved ethnographic field surveys carried out in Baojiatun from 2016–2017, designed to understand the use of TEK in response to weather disasters. We used four methods, presented in Table 1, to gain a comprehensive understanding of local knowledge of natural phenomena, traditional agricultural practices, social institutions, and mental perceptions.

Participant observation provides a stronger understanding of local farming life. Traditional agriculture and traditional rituals, reflecting ecological practices and social organization, are one of the aspects studied in participant observation. Some of our conversations took place while the interviewees were working, for example, preparing ritual paraphernalia or irrigating farmland. In addition, we were invited to participate in an ancestral festival held in the village in 2016, and observed how community members maintain clan social organization through rituals that commemorate their ancestors. We stored data from participant observations in the form of photos and videos.

The interviews were quite challenging to carry out in rural areas. Because the TEK is often perpetuated through physical practices and oral transmission, and the local residents were so accustomed to their daily practices, perceptions, institutions, customs, and values, they could not clearly articulate the corresponding ecological functions. Semistructured interviews serve as an effective means to address these difficulties (Nakashima and Murray 1988, Nakashima 1990, Huntington 1998). To govern the general direction of the semistructured interviews, we distilled an analytical framework of TEK from the relevant literature and on-site observations of the landscape elements that may concern TEK made in the first round of surveys. This included the following: (1) village history, folklore, and intangible cultural heritage; (2) traditional use of natural resources such as topography, rocks, soil, native flora and fauna by villagers; (3) traditional agricultural cultivation and farming; (4) beliefs about natural phenomena such as meteorology; and (5) rituals related to these beliefs or ways of organizing society. Baojiatun has a total of 31 compound houses, each of which is inhabited by three to eight households of permanent residents. We visited and interviewed one householder from each house.

We also held an analytical seminar, for which we invited indigenous residents and natural scientists to explain the ecological concepts, institutions, customs, and practices of traditional communities from their perspectives. The scientific discernment of TEK is best explored by organizing a joint discussion (Huntington 2000). However, due to limitations, we divided the interviews into two types: interviews with residents (the Old Han with traditional knowledge) and consultations with experts (the New Han with scientific knowledge). Natural scientists, as holders of scientific knowledge, explained the ecological functions of local landscapes and the scientific rationality behind traditional ecological practices, which tested traditional notions of human–land interaction, distinguishing
between “scientific knowledge” and “beliefs and superstitions,” and thus provided an opportunity to explore whether and how “beliefs and superstitions” support traditional ecological practices and where they fit into the cultural system of the community.

Although it was difficult for many of the busy farmers to attend a workshop, we invited 10 participants to discuss natural phenomena used as indicators of meteorological patterns, plants and animals perceived by community members in their farming practices, and the participants’ responses to the indicated climatic phenomena. The workshop aimed to understand the local people’s adaptive capacity to weather hazards. The participants were all men around the age of 50, comprising the main workforce and heads of their families in the community. By exploring the plants, animals, and climate phenomena that can help indigenous people predict weather hazards, we worked together to complete a display board. Based on this, we asked the following questions: (1) What measures do you generally take in order to respond to weather hazards? (2) How do people in the community carry out these responses, how are they organized, and who is responsible for them? and (3) What are the principles and taboos when performing these operations?

The third round of follow-up interviews held in 2020 focused on the residents’ observations, perceptions, and predictions of and adaptation to changes in the occurrence and intensity of meteorological hazards. Given the trust established with the villagers earlier on, a list of questions was distributed. We entrusted the consultation list to the village chief, who distributed the list to seven “community experts.” The “community experts” included five male householders and one young man and one woman who spend most of their time in the community and who were considered most likely to apply their knowledge to agricultural activities. The following questions were posed: (1) have you observed changes in temperature, rainfall, and other weather phenomena in Baojiatun in recent years? Have you observed changes in plant and animal growth and activity? (2) If so, what changes have you observed? (3) How have these changes impacted local agriculture and irrigation? (4) Do you think that these changes will continue, and how may they change in the future? (5) What are you doing to address these changes?

**Data analysis**

Our data analysis procedures were based on the grounded theory approach (Creswell and Poth 2017). Once we had completed all of the field studies, our data were transcribed into MAXQDA software (Gizzi and Rädiker 2021). We analyzed the information collected in the second round of investigation based on the preconstructed TEK analysis framework and then created codes. We first performed in-depth coding to extract different codes from the data and associate them with the different categories. Then, we matched the categories derived from the open coding with the preconstructed TEK framework and then created codes. We then began to organize and understand specific aspects of the climate adaptation knowledge derived from our analysis by combining groups and categories. Such data aggregation allowed us to assess how TEK can be used to observe, adapt, and mitigate the consequences of climate change.
Table 2. Coding illustration of the qualitative data from Baojiatun.

<table>
<thead>
<tr>
<th>Step</th>
<th>Content/Label</th>
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<tbody>
<tr>
<td>Raw data (examples)</td>
<td>(Farmer workshop recording/Data set 1: Irrigated agriculture) We have a folk rhyme here “‘cat’s thorn is in bloom when planting’” (1), which means that when the cat’s thorn is in bloom, it is time to sow rice and corn (2). The “cat’s thorn” is a nickname for the plant that grows along our river. I can show you (3). Then, March and April is when rapeseed flowers are in full bloom, golden yellow, starting from the Pure Brightness (2). There are many animal phenomena then, and small animals come out of hibernation. Ants and snakes come out of their nests at the time of the Waking of Insects, and pests become plentiful (4) ...</td>
</tr>
<tr>
<td>Code</td>
<td>1 Plant phenomena observation 2 Crops 3 Identification of native plants 4 Animal phenomena observation 5 Perceptions of weather changes 6 Farming tools 7 Use of livestock 8 Use of water power 9 Ancestor worship 10 Geomancy 11 Reverence for nature 12 Characteristics of dams 13 Reasons for building dams 14 Annual repairs 15 The method of planting 16 Cooperation ...... 93 Beliefs 94 Cultural rituals 95 Clans</td>
</tr>
<tr>
<td>Category</td>
<td>a1 Agricultural cultivation and irrigation (1,2,6,7,8,13,15,16) a2 Construction and maintenance of dam and canal systems (10,11,12,13,14,16,17) a3 Nature conservation actions (1,3,4,5,11,15,36...74,76) a4 Climate awareness (1,3,4,5,10,11) a5 Preparedness for climate disasters (1,3,4,5,11,15,16,95) a6 Community self-organization (9,16,17,18,19...94,95) a7 Local custom transmission (9,20,22,23,32...93,94) a8 Responsibility for environmental protection (11,15,18,26,29...66,84) a9 Collective moral obligation (14,16,20,33,41...83,93) a10 Views on nature and the universe (5,9,11,70,72,88,93,94) a11 Leadership role (9,14,17,33,40,79,80,95)</td>
</tr>
<tr>
<td>Group</td>
<td>A1 Worldview (a9, a10) A2 Social institutions (a6,a7,a9) A3 Management systems (a1, a2,a3,a8,a9,a11) A4 Perceptions of climate change (a4,a5)</td>
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RESULTS

Traditional Ecological Knowledge in Baojiatun

Confucian ethics: beliefs and social institutions

The data aggregation showed that the participants had a keen awareness of environmental changes based on their care for heaven and earth. Their responses to climate phenomena demonstrated the principle of following the laws of nature, and the organization of actions in response to weather disasters underscored the self-organized characteristics of clan society. The traditional Han Chinese Confucian belief in the “universe” is equivalent to the religious meaning of “God,” and it is firmly believed that only by revering and respecting heaven and earth can human production and life be satisfied. According to the villagers’ behavior when preparing the ritual paraphernalia, the people of Baojiatun have inherited Confucian beliefs and created shrines for figures such as San Guan Da Di (Official of the Earth, the Water, and the Universe) and Shen Nong (Patron of Agriculture). These beliefs are passed down through the intergenerational transmission of oral traditions. For example, elderly individuals will tell the younger generation the idea that “the top does not touch the universe and the ground does not touch the earth” when writing on the shrine, which deepens their worship of the universe and earth. We inferred from the data set group of life and socialization that Baojiatun is mainly home to people with the surname Bao, and it is a typical clan society with a firm tradition of revering ancestors. As a result, the structure of the social organization created by the village elders has always governed the allocation of power and prestige in the village, and Baojiatun has maintained a system of self-organization. According to the data set group of governance and social organization, self-organization plays an important role in calling on villagers to preserve the forests, conserve soil and water, and protect seedlings for the common good. As the most typical example, annual water and irrigation project maintenance (called “annual repair”) is executed as part of a voluntary project organized by the chief of the clan, helping individual families to preserve irrigation facilities.
Clan doctrine motto: water and soil resource management systems

Based on our semistructured interviews with villagers who were working on water irrigation, local rules and regulations constituted the “written laws” of patriarchal society, and their deterrent effect exceeds that of ordinary laws and regulations. The data set group of governance and social organization shows that the community of Baojiatun applies a number of local rules concerning the protection of water and soil resources. One of the earliest rules is an old doctrine calling upon the people to not destroy irrigation facilities, to cherish water resources, and to prevent the water level from dropping. In the 6th year of Xianfeng (1856 A.D.), during the Qing Dynasty, the following heavy penalties were established: “We prohibit the poisoning of fish, the digging of dams, and the netting of fish; the penalty for violators is silver money of one Liang and two Qian (60 grams of silver).” In the Republic of China period, Baojiatun residents edited the “clan doctrine motto,” which encouraged the conservation of the mountains and forests to include the following “Birds, animals, and moths love their lives, do not hunt in or burn forests.” Today, the “Red 15” of Baojiatun clearly prohibits deforestation and indiscriminate logging. From the “clan doctrine motto” to the “Red 15,” the local rules appear to be more official, losing the expressions of ecological ethics. In addition, according to the interview with one member of the 31 households who was the previous chief of Baojiatun, the ancestors of the Bao clan once set up a system of “annual repair” with a stone monument erected in a temple, which has become an ancestral instruction. This has maintained the efficient operation of the local irrigation system and the sustainability of agricultural activities.

Solar terms: local knowledge of phenological changes related to the seasons

In Baojiatun, weather, plant, and animal phenomena are used as indicators of the farming season (Fig. 3). From the pure brightness (4–6 April) to grain rain (5–6 June) periods, rice crops should be sown. During this time, the bees are busy pollinating flowers. A shrub called “cat’s thorn” grows in Baojiatun, and the phrase “cat’s thorn is in bloom when planting” states that when “cat’s thorn” blooms, it is time to plant rice seedlings. In addition, from the pure brightness to greater heat (22–23 July) periods, there is continuous thunder and lightning accompanied by heavy-to-torrential rain. According to the experiences of the Baojiatun people in previous years, a rise of approximately 20°C over 5 d indicates that the grain in beard period is essentially over and that

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**Fig. 3.** Diagram showing the phenological changes as “Indicators” of the farming season in Baojiatun (information source: the workshop on indicators).
sowing should be concluded at this time. In addition, when the number of tadpoles in river water starts to increase significantly, this also indicates the arrival of the grain in beard period. After this period, the river water level rises, and temperatures approach 30°C, which indicates the arrival of the lesser heat period (7–8 July); when the water level falls, this indicates the arrival of the beginning of autumn (6–9 August). The Baojiatun saying, “The water rises 18 times after the summer solstice (21–22 June),” means that the 18 increases of water levels after the summer solstice mark the arrival of the end of the heat period (22–24 August) or of autumn. Animal phenomena can also indicate the start of this period, and the sound of frogs denotes the beginning of summer (5–6 May); after the lesser heat period and before the end of the heat period, the ground grows hot, infested with snakes and pests. The water level changes during this period, making it essential to take drought and flood control actions. Half a month after the first day of the end of heat period, temperatures drop significantly, the sky grows overcast, the number of sunny days increases, and white frost appears on the grass, marking the start of the white dew period (7–8 September). Rice is usually ripe for the autumn harvest within 10 d around the time of the white dew period. Between the arrival of the white dew period and the end of the frost’s descent period (23–24 October) is a good time for villagers to harvest duck eggs, snails, fish, and shrimp. During this period, ducks lay and hatch eggs, snails multiply vigorously, and fish and shrimp are especially abundant in the river. In addition, the people of Baojiatun predict rain conditions according to the weather based on sayings such as “The spring cold comes with rain, and the summer cold comes with clear skies.” At the beginning of autumn and the end of the heat period, residents of Baojiatun use wind directions to judge sunny and rainy conditions: “Southeast wind brings clear skies, and northwest wind brings rain.” The date of the first snowfall in greater snow period (7–8 December) is often remembered by the people of Baojiatun, and it is said that “The water level rises 100 d after the first snowfall.”

Dragon mouths: disaster risk mitigation based on ecological knowledge

The main meteorological disasters that occur in Baojiatun include floods, droughts, and hailstorms. The water level is unstable, and rapid flooding occurs during the high water season. The people of Baojiatun have addressed this problem by building two dams. When the river water level rises rapidly, excess water in the “Yima weir” can flow over the long side of “Yima dam” into the old river to prevent the flood from directly flooding the rice fields: between the new and the old rivers is a flood relief channel, for which the “Shun dam” plays a role in blocking the river and pedestrian traffic. During the flood season, the excess water can flow over the “Shun dam” and merge into the “old river” such that the “new river” can maintain a stable water level. At this time, it is not appropriate to walk on the dam because, as the locals say “people give way to the water.” During the dry season, the river is at risk of drought. Therefore, Baojiatun’s ancestors built “dragon mouths” (caves that can be manually opened and closed for drainage) to allow the amount of water diverted in front of each dam to be adjusted. Each dam, with the exception of the “Huilong dam,” has a low dragon mouth and several high dragon mouths of different depths. The high dragon mouths regulate the amount of water flow, and the low dragon mouth is used for rapid drainage in cases of emergency. The people of Baojiatun use the phrase “good crops in a dry year” to refer to the fact that there is no shortage of water under dry climatic conditions and that high temperatures and long periods of sunshine are compatible with sufficient volumes of water in Baojiatun, which in turn improves crop harvests. The lyrics of a local song of Baojiatun say, “If we maintain water conservancy facilities to meet the needs of heaven, we can take the initiative to prevent disasters for a good year.” In addition, the people of Baojiatun have developed a set of measures to protect against hail. When hailstorms occur in the spring and summer, the residents fill the rice fields with river water in advance to limit the impact of hailstones and then melt them to ease freezing damage so that the hailstones do not damage the seedlings and freeze their fragile roots.

Role of Traditional Ecological Knowledge in Climate Change

Observations and perceptions of climate change

All of the villagers interviewed had noticed the environmental variations brought about by climate change, intuitively sensing that temperatures had increased over the last decade. The summers were considered warmer than before, whereas winter temperatures were approximately 2°C higher. Regarding changes in plant growth, on the one hand, the villagers felt that the seasons were distinct and could still use phenology to predict the timing of farming cycles; on the other hand, the villagers felt that plants had grown healthier and that the number of animal species had also increased. However, they believed these patterns to not necessarily be a consequence of temperature changes and viewed them as a “good thing” for the settlement environment. They considered this to denote that “the ecological environment was improving, benefiting life and farming after all,” although more mosquitoes interfered with the inhabitants’ lives in the summer and the invasion of wild plants on uncultivated land sometimes created challenges for the farmers. The villagers’ phenomenological observations of the effects of climate change are subtle and optimistic, demonstrating consistency with their natural values of caring for and worshipping the heaven and earth.

Another “good thing” that has come from climate change is a reduction in the number of hailstorms. Ten years ago, the spring and summer were often accompanied by hailstorms, but now summer hailstorms are almost nonexistent, and spring hailstorms have decreased. Subsequently, mechanisms for mitigating hailstorms have rarely been invoked. In 2010, Guizhou, where “the sky never clears for three consecutive days,” experienced a drought that had not been seen in a century. In many areas of Guizhou, farmers experienced total crop failure and had to rely on the government to deliver water. Since Baojiatun is located downstream of a fracture area, it is relatively rich in water resources. Although the upper reaches of the Xing River had dried up, groundwater drawn before the Yima dam could meet irrigation requirements. A villager said, “At that time, residents from the surrounding villages came to Baojiatun to borrow rice to maintain their seedlings.” In addition, the effectiveness of their irrigation system in mitigating climate change was highlighted: “Baojiatun has a complete irrigation and water system and has not been affected by any disasters for hundreds of years.” However, the villagers felt that the number of floods seemed to have increased, making it no longer accurate to speculate on the arrival of the limit-of-heat period based on the saying “the water rises 18 times after the summer solstice.”
Behavior in response to climate change

In general, the villagers’ attitudes toward climate change and its impacts were positive, and they believed their ecological practices, which had been handed down for generations, to be able to withstand climate risks and resolve such crises. On the one hand, the physical and functional aspects of irrigation projects have been well preserved. Given that the villagers have used ancient irrigation projects to resolve one weather disaster after another and as Baojiatun’s farming economy has not been affected in any way for hundreds of years, the residents are confident that they will be able to resolve future crises. On the other hand, some villagers noted that principles of environmental conservation had been effectively passed down from generation to generation by their ancestors and that with its strong culture of agriculture and deep-rooted ideologies of ecological protection, Baojiatun will not change much in the future. With the support of the village’s self-flowing irrigation system, the villagers felt stable in the farming activities with stable harvests, so they were happy to maintain a small farming economy and the agricultural landscape that they were proud of.

The villagers were convinced that their ongoing ecological conservation practices served as a response to climate change. They believed many of their actions to be beneficial in the midst of climate change by protecting the forest, maintaining irrigation facilities, and forbidding hunting, as called for by their ancestral motto. In recent years, with the expansion of the village and the improvement of fishing tools, the villagers have established many new rules and regulations which in their minds have been conducive to the mitigation of environmental disasters, including sewage disposal regulations, fish poisoning sanctions, and straw injunction (stalks left after the harvesting of sorghum) burning regulations. Extracting rocks from mountains covered by primitive forests and cultivating farmland on mountains above 25 degrees in slope are also prohibited. The residents also believe that ideological-level measures such as compliance with and the inheritance of local regulations, raising awareness of environmental protection, and emphasizing agriculture increase resilience to climate change. We found that the villagers could not explain the rationale for each response to climate change and that their convictions were more rooted in their beliefs. The villagers were confident that climate change would not affect Baojiatun in the future as long as they adhered to ideologies of ecological conservation passed down through the centuries and employed new response measures as appropriate.

DISCUSSION

We focused on whether TEK is sufficient to support the adaptive capacity of traditional communities in the face of contemporary climate change. We first inferred that TEK concerning climate change is a system based on a knowledge–practice–belief complex with an inherent causal logic (i.e., the worldview is the central motivating factor governing social institutions, management systems, and perceptions of phenomena that guide meteorological disaster risk mitigation) (Berkes et al. 2000, Lantz and Turner 2003: 265). Through our study of the village of Baojiatun in the karst depression on the Yunnan-Guizhou Plateau, we found that (1) Baojiatun is a collectivist community with ideologies of nature worship and ancestor reverence at its cultural roots and that all of the villagers are bound by local regulations established to maintain natural resources and traditional agriculture. The villagers use phenology as an indicator to predict natural disasters related to farming production and use a resilient infrastructure system of canals and dams to prevent such disasters. (2) The villagers of Baojiatun have observed natural phenomena such as rising temperatures, more intense droughts and floods, fewer hailstorms, and flourishing flora and fauna in the last decade, and these natural phenomena have not impacted their agricultural production or livelihoods. The villagers are not worried about climate change itself as they believe that their superior environmental conservation mindset and resilient infrastructure can withstand the risks posed by these phenomena. (3) The villagers of Baojiatun are confident in the possibility of relying on TEK to address contemporary climate change, believing that their village’s historically tested practices have demonstrated an ability to mitigate change. Moreover, they have adhered to core beliefs of natural conservation and extended new regulations and practices to address new crises. (4) Social factors such as urbanization, organizational disintegration, and lifestyle changes are more serious challenges for TEK maintenance than natural disaster uncertainty caused by climate change, and the loss of TEK threatens the climate adaptation of Baojiatun.

We find that TEK’s contribution to socioecological system resilience lies first in keen perceptions of change by local people, a perception that allows the system to regulate change more promptly and effectively (Walker et al. 2004, Berkes et al. 2008, Tavares et al. 2015). For 600 yr, Baojiatun villagers have closely linked their agricultural livelihoods to weather phenomena. Today, they still use traditional methods to determine the timing of agricultural tasks by observing phenological cues such as plant flowering and growth, insect activity, and river water levels. This traditional observation method allows them to remain alert to weather changes and to the plant and animal phenology associated with these changes, and this alertness helps them make timely disaster preparedness decisions and predict the ensuing changes. Echoing the results of Yang et al.’s (2019) study of traditional villages on the Pamir Plateau, villagers in Baojiatun have deduced through plant and animal phenology that the local area has recently become warmer and wetter than it was a decade earlier, which is an empirical observation consistent with climate records (Gu et al. 2018).

Although this empirical observation is driven by agricultural livelihoods, we see that the corresponding results have contributed to systematic resilience and to the villagers’ adaptation to climate change. This contradicts Bruun and Olwig’s (2015) concerns. They found in their case study that knowledge about how to cope with adverse climate and environmental conditions is hardly “resilience” and “equilibrium” oriented. Instead, the anthropocentric, sometimes opportunistic, and barely existing robust entities of TEK can support disaster or climate change mitigation initiatives. In the case of Baojiatun, TEK, despite its economic emphasis on the development of future human generations, cannot be called anthropocentric. Rather, TEK has an ecocentric view of local ecosystems and of the role of humans in them, arguing that all animals have a right to survival that is independent of their usefulness for human purposes. For example, Baojiatun’s ancestral motto, “All birds, animals, and moths love their lives; do not hunt or burn the forests,” coincides with a statement made by deep ecology advocate Arne Naess: “The right
RESEARCH AND MANAGEMENT IMPLICATIONS

Many studies have demonstrated that climate change has particularly dramatic impacts on communities that depend on natural resources for survival (Salick and Ross 2009, Riva et al. 2013, Francesca 2016). Our study further demonstrates that indigenous people effectively mitigate this impact with TEK (Armitage et al. 2011, Nakashima et al. 2012, Boillat and Berkes 2013, Ignatowski and Rosales 2013, Leonard et al. 2013). Traditional ecological knowledge helps indigenous communities cope with environmental and climate stresses and promotes the resilience of SES (Hosen et al. 2019, Williams et al. 2020). The analysis provided in this paper suggests that TEK’s contribution to socioecological resilience lies first in maintaining indigenous people’s sensitivity to change, second in the fact that TEK is a flexible complex centered on an eco-centric perception of local ecosystems and of the role of humans in them, and finally in the fact that this perception triggers adjustments where the complex is inclusive of adjustments needed to respond to changes. Although our third survey was conducted during the COVID-19 lockdown period and our method of screening interviewees through the village chief may have produced some bias, our data and other similar studies (Liedloff et al. 2013, Fernald et al. 2015, Inaiotombi and Mahanta 2018, Carter 2019, Matera 2020) are sufficient to support our view that TEK plays a key role in enhancing the adaptive capacity of systems to cope with environmental change (Berkes et al. 2000). Traditional ecological knowledge supports socioecological resilience because it encourages indigenous people’s sensitivity to change and provides an adaptable knowledge system with a strong eco-centric view of nature that can support adjustments and is flexible enough to accommodate the adjustments required to respond to changes. Our study enriches the findings of TEK research on indigenous people’s understanding of ongoing climate change and of the measures they take to cope with it (Pearce et al. 2015, Armatas et al. 2016, Williams et al. 2020). Furthermore, following the call of Armata and colleagues (2016), in the discussion of existing literature on TEK concerning climate change, we have integrated TPK as part of our argument for the key features of TEK that support adaptation to climate change (Lantz and Turner 2003). The TEK framework for climate change constructed in this paper can provide important directions for future research identifying indigenous peoples’ knowledge in observing, adapting to, and mitigating the consequences of climate change.

Global climate change and its resulting natural disasters are pushing the limits of socioecological resilience, disproportionately affecting the poorest and most marginalized communities living in vulnerable areas. Inappropriate land use and resource exploitation are likely to further threaten the ecological stability of vulnerable areas. Our study of the traditional “Old Han Chinese” community of Baojiatun found that the people of Baojiatun make long-term and close observations of all natural elements that they can perceive with respect to nature and the earth. From their knowledge of these natural phenomena, they have gained practical guidance for water management, disaster resistance, and planting and breeding. From the experience of nature management, TEK helps indigenous communities understand new changes in nature that continue to shape the landscape (Li et al. 2016, Li and Han 2017). This behavior logic is consistent with an ancient Chinese moral–philosophical treatise of all the forms to live is a universal right which cannot be quantified” (Naess and Rothenberg 1989: 166). The villagers of Baojiatun have strictly protected local mountains, forests, soils, and rivers to ensure the continuation of these important natural resources out of a deep admiration, appreciation, and reverence for nature and the earth. Therefore, we believe that TEK is characterized by deep ecology that emphasizes the maintenance of the ultimate goal and core value of living in harmony with nature where all management systems and ecological techniques are implemented to adapt to natural conditions and changes. This is corroborated by the plans of Baojiatun villagers to cope with future changes: they confidently believe that the most important goal is to maintain the traditional concept of cherishing the natural environment.

Baojiatun villagers believe that adapting management measures to change is acceptable and should be encouraged as long as core views of nature are maintained. In Baojiatun today, some traditional observations are being abandoned or improved as the climate changes. For example, the scale of summer flooding has become so great that villagers no longer use the traditional mantra “The water rises 18 times after the summer solstice” to predict the arrival of the summer season, and the opening and closing of the “dragon mouth” to regulate the water levels is also adjusted according to changes in flood conditions. In addition, with the expansion of the village and the improvement of fishing tools, the villagers of Baojiatun have developed and enforced many rules and regulations. Such adjustments include adaptation processes designed to help local people cope with observed or expected environmental changes and their impacts (Nelson et al. 2007). Local populations’ capacity to adapt management tools and practices in response to systemic disturbances (climate change, ecological disturbances, or socioeconomic upheaval) promotes the ecosystems’ ability to recover and reorganize as quickly as possible to mitigate the adverse effects of such disturbances (Holling 1996, Brown and Hay-Eddie 2014). This mechanism of generating regulatory measures based on core deep ecological values enhances the system’s resilience in the face of climate change (Zhou and He 2015). Traditional ecological knowledge plays an essential role in maintaining the resilience of an SES in response to change because it is an open complex with a view of nature as a trigger that is flexible enough to accommodate the adjustments needed to respond to change, yet stable enough to adhere to the core values of deep ecological conservation.

Similar to Bruun and Olwig (2015), we are concerned about the continuation of TEK in a changing social environment. Although the Baojiatun community still retains a relatively strong rural identity, its traditional institutions are being challenged as the sociological differences between rural and urban areas generally decrease during China’s rapid economic growth. It is the ethics and morals at the root of Baojiatun’s TEK that endow its people with the ability to cope with climate change. However, our results show that the local rules have been more juridical, with the interpersonal and environmental ethics of ritual society no longer strictly defined. The change from a Gemeinschaft (ritualistic society) to a Gesellschaft (juridical society) is a trend in rural China (Fei 2012: 9–16) that may affect TEK’s ability to cope with climate change. Our suggestion for this is to embrace development while preserving the principles of deep ecology that are at the core of traditional knowledge.
on the self-cultivation of life, the “Zhongyong,” which states that “Those who are worthy to help Mother Nature in growing and sustaining life are the equals of heaven and earth” (Lin 1938:123). Traditional ecological knowledge inheritance is essential in affording local people the confidence to cope with harsher climate change impacts in the future and the confidence to act as competent resource stewards and strategy developers. In a global context of social change that leads to the loss of traditional culture, the intergenerational transmission of TEK is challenged; thus, the role of TEK in supporting indigenous climate change adaptation may decline. This paper does not deliberately exaggerate the role of TEK or advocate for the evolutionary indigenous communities to adhere to it; rather, we argue that TEK possesses merits as a flexible and adaptive open system with a strong ecocentric view of nature. The combination of TEK with scientific knowledge and management approaches to address future global climate change is worthy of further research.

Author Contributions:

Han Feng: funding acquisition, project administration, resources, supervision, investigation, writing - review. Li Jing: conceptualization, methodology, investigation, writing - original draft preparation, writing - revision.

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Data Availability:

The relevant data and codes are available from the Ministry of Science and Technology of the People’s Republic of China. The availability of these data is restricted and they can be accessed after their confidentiality period with the permission of the Ministry of Science and Technology of the People’s Republic of China.

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