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Research

Common and Privatized: Conditions for Wise Management of Matsutake Mushrooms in Northwest Yunnan Province, China

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ABSTRACT. Since Hardin's (1968) paper on the "Tragedy of the Commons," property rights of common-pool resources have been a central concern for natural resource management scholars. Matsutake, a common-pool resource, is an economically important mushroom in several locations around the world. Driven by growing international demand over the last few decades, matsutake management is a relatively new practice both for local communities and government agencies. In Northwest Yunnan, China, one of the most productive areas for matsutake globally, numerous local practices and systems have emerged in the last two to three decades. In this study, we investigate the differences between management systems in eight communities and the factors associated with them. The methods used for field research included key-informant interviews, household surveys, and questionnaires. Three main management patterns were identified through use of statistical clustering based on indicators such as physical environment, resource characteristics, tenure arrangements, regulations and implementation, harvesting behavior, income, and market regulation. It was found that private access—the principal characteristic of which is the exclusive use of resources—results in more income at lower labor cost per household than either of the other open-access management patterns. Even though under the context of ongoing Second Forest Tenure Reform in China—in which collective forest privatization is the key task—application of private-access regimes is limited because of site conditions including physical, institutional, and market environments. Common-access management systems have advantages in terms of managing conflict and balancing equity needs. No matter the type of access right, the key issue for wise matsutake management is institutional. Locally rooted innovative strategies should be encouraged, and institutional capacity building should be carried out to support innovations in matsutake management.

Key Words: *common-pool resource; management strategies; Matsutake mushroom; open access; privatization; Yunnan Province*

INTRODUCTION

The governance of common-pool resources (CPRs) has important implications for both conservation and development. Following Hardin's paper on the "Tragedy of the Commons" (Hardin 1968), tenure and property rights have been considered central to CPR management (Bhattacharya and Lueck 2009). How can natural resources be managed properly? The paradigm of the prisoner's dilemma has often been taken as a model of the possible causes of the overuse of natural resources, especially open-access and common-property resources (Ruttan 1998), leading some to conclude that abandoning the freedom of the commons is the solution to resource depletion (Gordon 1954). There is also substantial evidence, however, that communal management of CPRs can be sustainable over the long term because there is strong local knowledge, practices, and institutions and a process of careful deliberation (Berkes et al. 2000, Dietz et al. 2003, Pretty 2003). Governing resource use is neither easy nor free of error (Ostrom et al. 1999). It has been shown that no single type of resource tenure—state, private, or community—is uniformly successful in halting significant resource degradation (Ostrom et al.

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1999, Dietz et al. 2003). Whether resources are common or privatized, however, is not the whole issue. The important questions are whether or not management is sustainable and cost effective, integrates various interests, and balances equity of usage. Conditions most likely to stimulate successful self-organized processes for CPR management are important (Ostrom et al. 1999), and an improved understanding of current management systems and factors determining the success of CPR governance is required (Sanginga et al. 2007).

Non-timber forest products (NTFPs) are frequently CPRs. Governance of NTFPs has not been studied in depth, although awareness of their importance for livelihoods and for reconciling conservation with development goals has increased (Arnold and Perez 2001). About 80% of the population of the developing world use NTFPs for health and nutrition, and several million households worldwide depend heavily on them for subsistence and/or income (Food and Agriculture Organization (FAO) 2002). They include a wide range of resources, from honey, bamboo, and rattan to medicinal plants and mushrooms; so it is difficult to generalize about NTFP management patterns. Given the diversity of resources falling into the NTFP category, it is unsurprising that there are few common analytical frameworks and strategies to guide their management or to analyze their impacts on livelihoods (Perez and Byron 1999, Belcher et al. 2005). Attempts have been made to develop typologies based on patterns of people's organization, state involvement, access and tenure rights, social attitudes, household economics, technology, market features, nature of the products, production systems, and environmental effects (Perez and Byron 1999); patterns of household economic strategies (Belcher et al. 2005); predicted impacts of commercialization on livelihoods (Newton et al. 2006); and more general local perceptions (Pandit and Thapa 2003). These studies compare cases involving different NTFP products. The attributes of a particular resource—size, carrying capacity, measurability, temporal and spatial availability of resource flows, amount of storage in the system, and speed of resource regeneration—may all lend themselves to particular management regimes (Ruttan 1998, Ostrom et al. 1999). There are strong grounds, therefore, for investigating the various management systems applied to the same NTFP resource. This approach is expected to provide more in-depth insight as well as conclusions of greater relevance to the impact of policies on the management of particular resources.

Matsutake are wild edible mushrooms that are soil borne and perennial mycorrhizal fungi (Ogawa 1975, 1976, 1977, Yamada et al. 1999, 2006). They attract global attention as a high-value seasonal delicacy with an average wholesale price of US$27–$60 per kg depending on quality and place of origin (Wang et al. 1997). Global demand for matsutake is driven primarily by the Japanese market.(Wang and Hall 1998). Around 3000 tons per year are consumed in Japan, two-thirds of which are imported from Korea, China, and North America (Yang et al. 2008). In Yunnan province, China, income from matsutake generates more revenue than all other agricultural exports and NTFPs, amounting to US$44 million of matsutake exports in 2005 (Yang et al. 2008). Harvesting and commoditization of matsutake in Northwest Yunnan only started in the late 1980s and early 1990s, before which they were seldom harvested. Historically, matsutake was used as a subsistence food or condiment and rarely sold to supplement income. As elsewhere in the world, mushrooms were considered "insignificant" in terms of both forest management and livelihoods (Yang et al. 2006), and their management was not governed by formal regulations.

Forest tenure arrangements made at the state level affect village-level incentives (or disincentives) for local institutional development. Since 1981, China's State Forestry Bureau has carried out the first Forest Tenure Reforms (*linquangaige*) (Wang et al. 2004). Forests tenure was allocated among two broad categories: state forests (*guoyoulin*) and collective forests (*jitilin*), some state forests were declared protected areas (*baohuqu*), some collective forests were divided into freehold forests (*ziliushan*) or contracted to individuals (*chengbaoshan*). More than two-thirds of forest lands where mushrooms are commonly harvested in Yunnan are collective.

Since the international market for matsutake has grown, their value in this remote mountain area has increased greatly, leading to frequent community-level conflicts (Yeh 2000). Overexploitation and unsuitable management practices have led to a significant decline in production. At the national level, matsutake is a protected species under the Convention on International Trade in Endangered Species (CITES). It is management at the

community level, however, that has direct impacts on the sustainability of matsutake resources and associated economic activities in the province. At the community level, demand for the regulation of matsutake management has developed, involving higher levels of government when communities have been unable to resolve conflict issues independently (Xu and Ribot 2004).

Various management strategies have developed and evolved, ranging from complete open access at one extreme to private management at the other. The rapid and increasing commercial harvest of matsutake and the management systems that subsequently developed provide an excellent opportunity for studying the management of NTFPs and the interplay between social and ecological systems. In the context of the ongoing second phase of Forest Tenure Reforms (Xu and Jiang 2009), in which forests that were previously collectively owned are being allocated to individual households and their use effectively privatized, this study provides insights into how CPRs like the matsutake mushroom can be managed properly. We analyze the locally implemented systems in Yunnan Province, Southwest China, for managing matsutake mushrooms and their habitat, and investigate factors associated with the adoption of different management systems. We investigate, also, the performance of management systems and the physical and institutional conditions under which different management systems developed in order to identify the critical pre-conditions for the introduction of improved management systems in the region.

METHODS

Analytical Framework

We attempted to understand the various strategies that have developed and evolved for matsutake management by answering three key questions: (1) What variations in management strategy exist? (2) Under what conditions are certain management strategies developed, and which factors shape the development of different strategies? and (3) What are the outcomes of each management strategy? We developed a simple framework (Fig. 1) to generalize the holistic natural resource management system by breaking it down into three components and depict the links and relationships among these components. As shown in Fig. 1, a certain management strategy is adopted or developed under specific socioeconomic and ecological settings and results in specific management outcomes. Conversely, outcomes could cause demand for modification of the management strategy and gradually cause changes in the social and natural setting over a longer period.

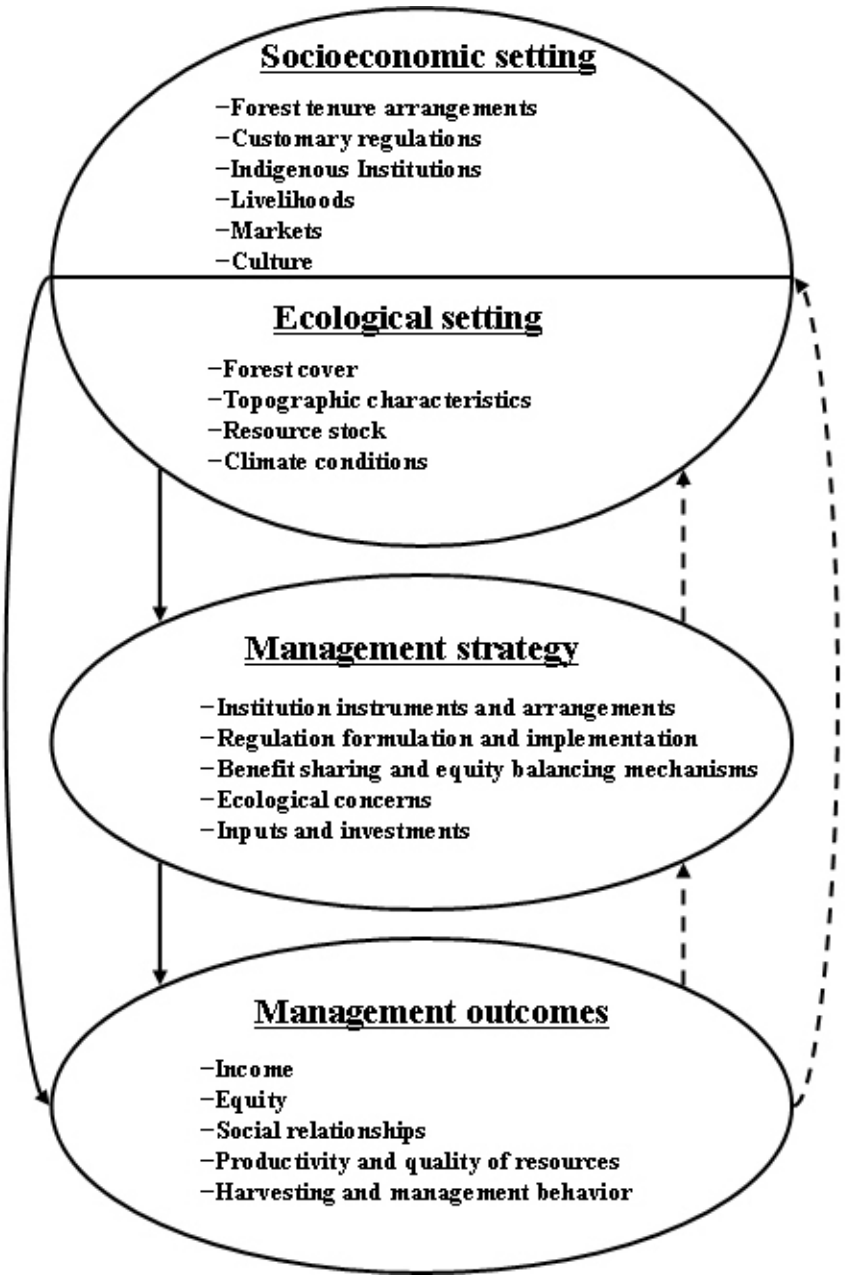
Guided by this analytical framework, we carried out a comparative study of eight management cases. In order to understand the patterns across these eight cases, we categorized the eight cases into three typologies, using a clustering method based on a group of selected socioeconomic and ecological indicators (see below). We then analyzed the three management typologies according to their institutional context institutions, regulation, benefit sharing and equity, and ecological attributes. Finally, we evaluated the performance of the three typologies based on indicators of income, harvesting behavior, product quantity and quality, social relationships, and equity. Data were collected from the eight study sites at two levels, the community and household levels. The typology identification analysis was implemented at the community level, whereas the comparisons of patterns and outcomes were evaluated at both levels.

Research Sites

More than 40 counties in Yunnan are reported to harvest matsutake (CITES-Kunming Office). These are mainly in Central, South, Northwest, and West Yunnan. Northwest Yunnan is important among them as it is the most productive (Yang et al. 2008). Located in the foothills of the Eastern Himalayas, its topography is very diverse, resulting in a variety of microclimates and rich botanical diversity. With 40% of Yunnan's 15 000 plant species, Northwest Yunnan is recognized as a global biodiversity hotspot (Myers et al. 2002).

The authors made several field visits (Table 1) to sites in Northwest Yunnan from 2000 onward and hosted two workshops ("Sustainable Use and Conservation of Matsutake in Yunnan: Policy, Trade, Research and Management" in Shangri-La, Yunnan from 24–26 July 2006 and "Community Experience Exchange on Matsutake Management" in Chuxiong Prefecture from 26–28 September 2006). Through communication with numerous

Fig. 1. Analytical framework of the research.



government agencies, NGOs, research institutes and communities, eight communities among the major matsutake production areas in Yunnan Province were identified for this study (Fig. 2). Table 2 presents a summary of the characteristics of the eight communities surveyed. The communities were selected to represent a diversity of management approaches as well as site characteristics such as forest types, terrain complexity, economic status, and ethnicity.

Diqing Prefecture is the most important production area in Yunnan as it accounts for about 50% of total provincial exports (Yang et al. 2008), and we chose five communities from Diqing. The inhabitants of these communities are Tibetan agro-pastoralists. Located in the highest terrain in Yunnan (3000–4200m), these communities inhabit widespread and complex topographic areas with natural forest coverage intact. The habitats of matsutake mushrooms are oak (*Quercus* spp.) and pine (*Pinus* spp.) forests that are owned either by the state or collectively. These areas used to be isolated and relatively underdeveloped compared with the rest of the country. Only in recent years have they begun to attract mass tourism, which has brought opportunities for integration into the market economy (Melick et al. 2007). Before the national Natural Forest Protection Program (commonly known as the "logging ban") was introduced in 1998, timber extraction was the major income activity. Recently, tourism and NTFPs, such as matsutake, cordyceps, and morels, have become options for earning cash. Jidi is a very productive community for matsutake mushrooms. Over the course of 20 years, the approach to matsutake management has changed several times. Yeri is located inside Baimaxueshan Nature Reserve and the reserve office plays an important role in formulating and implementing matsutake harvesting regulations in order to establish long-term co-management arrangements. Kangsi tried forest enclosure to promote matsutake production and then reverted to free harvesting. A'dong introduced a rest-day system in which harvesting was not allowed on one day each week. In Zhiti village, where total yields were low, little attention had been given to developing and enforcing regulations.

Lizui is located in Lijiang Prefecture and inhabited by the Naxi ethnic group and by Han Chinese who are mainly agriculturalists. Like communities in Deqing Prefecture, Lizui is also isolated and the economy has shifted from logging to NTFPs. Haitang in Baoshan Prefecture and Kaimen in Chuxiong Prefecture are located at lower altitudes (around 2300–2600 m) with less complex topographic conditions. The inhabitants mainly depend on agriculture and cash crops. Since 1996, the Tropical Forest Research Institute of South China has carried out work to promote forest enclosure and has developed an ecological approach to improve matsutake production in Haitang. This approach included enclosing and protecting the matsutake habitat; prohibiting harvesting of baby mushrooms; showing villagers how to leave four or five mature mushrooms to disperse spores; experimenting with inoculation of matsutake mycelium in tree plots; and carrying out insect and animal control measures. Continuous observation showed that the total yield in Haitang increased from 110 kg in 1996 to 1800 kg in 2005. In Kaimen, with the help of the Forest Bureau of Nanhua County, contracted user rights were introduced 10 years ago to manage collective or common land where mushrooms grow. Mushroom harvesting rights were allocated and leased out on contract for given periods. The village committee was responsible for delineating the forest plots and leasing out harvesting rights to individual households or groups of households. Sometimes the contract was given to outsiders. Generally an open-bid process was followed. The income from the contracting fee was redistributed to the villagers.

Key-Informant Interviews

In each community studied, key informants were selected for interview and questionnaires administered about matsutake management issues. The information collected covered the following: (1) basic information about the village; (2) how the regulations were formulated and what their main contents were; (3) how the regulations were implemented and monitored; (4) what the benefit-sharing mechanisms were; (5) what the impact of forest tenure reform on matsutake management was and the local response to reforms; and (6) problems encountered in matsutake management. The informants were mainly village leaders, management committee members (if any), individuals responsible for enforcing regulations (if any), and locally acknowledged harvesting experts. The information was entered on an Excel® worksheet and used for the typology study.

Table 1. Relevant field research on matustake mushroom.

Time	Place	Activities	Research team
Jul–Aug 2000	Jidi	Matsutake trade chain survey	Center for Biodiversity and Indigenous Knowledge
Jul–Sept 2003	Jidi	Ecological and spatial distribution study	Kunming Institute of Botany, International Institute for Geoinfomatic Science and Earth Observation (The Netherlands)
Jul 2006	Jidi, Zhiti	Useful plant survey	Kunming Insitute of Botany
Sept 2006	Wujie (including Kaimen)	Site visit for workshop on exchange community experience sharing of Matsutake management	Kunming Institute of Botany
Sept–Oct 2006	A'dong, Yeri, Lizui, Wujie, Kangsi	Matsutake management system survey and DVD filming	Kunming Institute of Botany
Oct 2007–Jul 2008	Jidi, Bamei, Guzha, Jiangpo, Deqin County	Review of DVD and community discussion on optimum Matsutake management system	Kunming Institute of Botany, Conservation International
Jun–Oct, 2008	A'dong, Yeri, Kangsi, Jidi, Haitang, Kaimen, Lizui	Matsutake management system survey, questionnaire, and household interview	Kunming Institute of Botany, University of Hawai`i at Manoa, University of Wisconsin-Madison

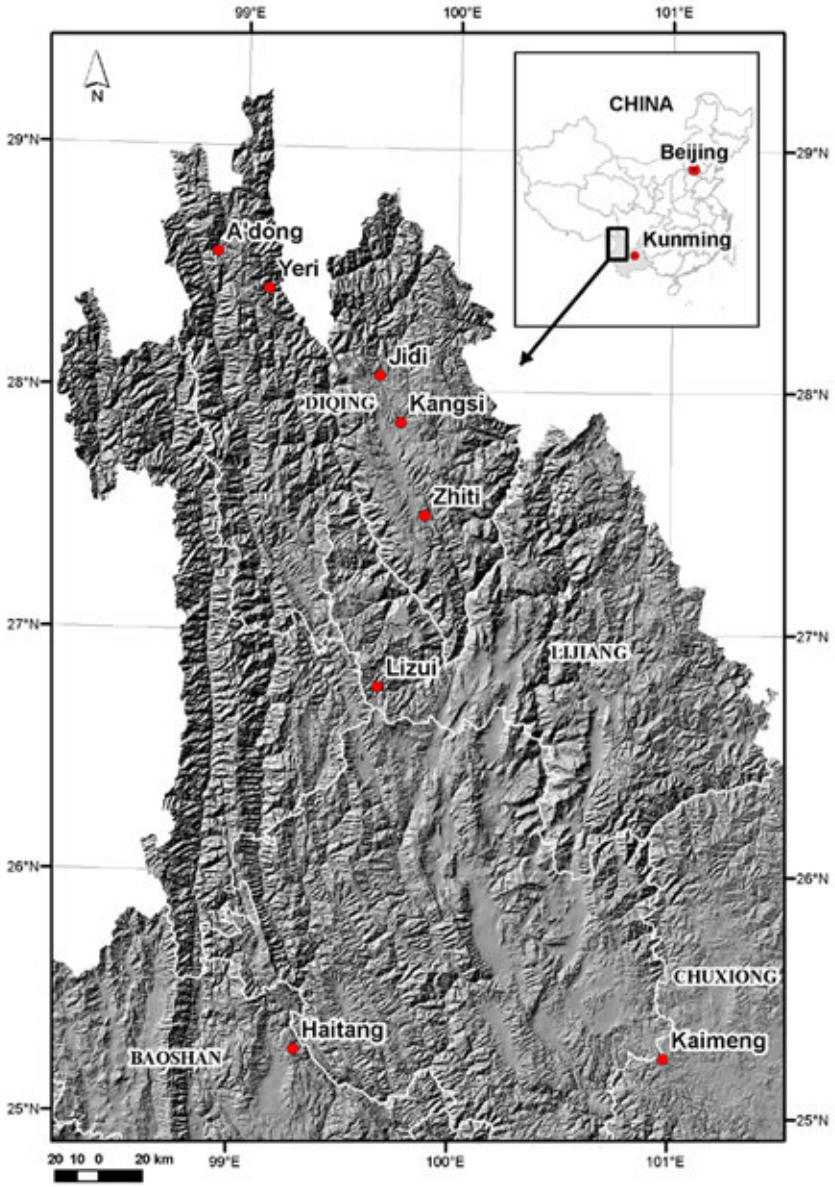
Household Survey

Households were visited and another questionnaire used to collect information about households, individual harvesting behavior, and the contribution of matsutake to household earnings. Households were sampled through stratified random sampling in which all households were categorized into three major groups based on the total income generated from matsutake harvesting; and two to four households were selected randomly for interview from each group in each community. In total, 67 households were interviewed in eight communities. The data were used mainly to compare the performance of each management strategy.

Typology of Management Practices

Numerous communities in Northwest Yunnan harvest matsutake mushrooms and they have a wide range of diverse approaches to managing matsutake mushrooms. In order to enable generalizations to be made from the diversity of real-world management systems, a typology of management strategies was developed. Hierarchical tree clustering is a statistical technique used for identifying patterns (Hansen and Jaumard 1997). Perez and Byron (1999) first used it to find patterns and develop typologies at the global level. Belcher et al. (2005) classified 61 cases based on household economic strategies. We followed the same approach to quantify and identify matsutake management patterns (Table 3). Analysis was carried out with a STATISTICA 6.0 software package (StatSoft 2001). As the selection of parameters such as amalgamation or linkage rules (e.g., single linkage, complete linkage, unweighted pair-group average, weighted pair-group average, and Ward's method) and distance measures used (e.g., Euclidean distance, squared Euclidean distance, Manhattan distance, and power distance) could affect the result, different combinations of the above-mentioned parameters were used. As there was no rigorous rule to determine which result is the best, we selected the one that occurred most frequently and which best matched the empirical data.

Fig. 2. Location of research sites.



Factors and Indicators Used for Pattern Analysis and Evaluation

Many authors have identified social and cultural institutions, tenure, local markets, household economy, resource abundance, and the relative level of development as factors that shape how resources are used (Ruiz-Prez et al. 2004, Cinner et al. 2005). Based on the available data and on research carried out before the survey, we considered forest tenure, institutions, management system, physical setting, matsutake yield, livelihood patterns, labor inputs, income, marketing, and harvesting behavior as the key factors for categorizing the eight cases into

Table 2. Basic information about the study sites.

Village Name	Prefecture	County	No. of house-holds	Ethnic groups	Occupations	Elevational range	Main vegetation types	Main management strategies
A'dong	Diqing	Deqin	405	Tibetan	Agro-pastoralism	3000–4200	Oak and pine	Rest day
Yeri			15			3100–4200	Oak and pine	Co-management with The Nature Reserve
Jidi		Shang-ri-La	24			3200–4200	Pine and oak	Rotational harvesting
Zhiti			25			3200–3700	Pine	No regulations
Kangsi			54			3300–4200	Pine	No regulations
Lizui	Lijiang	Yulong	344	Naxi	Agriculture	2400–4000	Pine	Centralized harvesting, marketing, and distribution of benefits
Kaimen	Chuxiong	Nanhua	359	Han, Yi	Agriculture	2400–2500	Pine	Contracted harvesting rights
Haitang	Baoshan	Baosh-an	45	Han	Agriculture	2300–2600	Pine	Household-owned forest management

Note: denotes data at the administrative village level, the other household numbers are at the natural village level. (In China, several natural villages constitute an administrative village.)

relatively homogenous groups. In total, 26 indicators were developed to characterize these factors (see Table 2).

Among the 26 indicators, some were numeric and quantitative, whereas others were binary or categorized types. To facilitate statistical analysis, categorized data were number coded. The explanation of the coding is given in Table 2. The assignment of a certain category was based on interview and empirical observation. For instance, we assessed the implementation of regulations based on our observations and impressions from the interviews. The matsutake habitat areas in the forests were identified by key informants from maps and areas calculated using geographical information systems (GIS). If more than one village shared the same habitat, the area was adjusted by dividing the total area by the number of villages. Similarly, the matsutake yield was adjusted if the estimated yield was from a shared market. In order to eliminate the effect of diverse data scales and units and to achieve a standard conformed comparison, all numeric data were standardized by scaling them to a range between 0–1 using the following Eq. 1.

$$y_i = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

Where x_i is the original data; y_i is the standardized data value; x_{min} is the minimum value of variable x; and x_{max} is the maximum value of variable x.

For the evaluation of different patterns and performance, we used data collected from 64 households. Fourteen variables representing income, alternative cash income, labor and time, and harvesting behavior were compared in the context of the three patterns identified. Box plots, which depict the median, quartiles, and extreme values, were used to illustrate the differences among

Table 3. Factors used for clustering management practices.

Factors	Indicators	Indicator types	Remarks
Forest tenure	Resource access	Category	1- Open access, 2- Collective access, 3- Individual/ Private access
	Boundary conflicts	Category	1. intro–inter village boundaries are clear; 2. inter-village boundaries are clear, whereas intro-village boundaries are not; 3.Both boundaries are vague
	Existence of regulations	Binary	0, no; 1 yes
Institution and management			
	Existence of monitoring committee	Binary	0, no; 1 yes
	Implementation status	Category	1- Restricted monitoring and implementation, 2- Moderate monitoring and implementation, 3- Poor/ no monitoring and implementation
	Equity in resource accessibility	Category	1- Equal opportunities for everyone, 2- Equal opportunities for most of the population, 3- Exclusive opportunities for designated population
	Resource-use pattern	Category	1- Individual competition, 2- Cooperative harvesting, 3- Contracted harvesting
	Benefit sharing	Binary	0- No benefit-sharing mechanism, 1- Benefit-sharing mechanism
Natural setting	Complexity of terrain	Category	1- Low spatial variation in terrain, 2- Moderate spatial variation in terrain, 3- High spatial variation in terrain
	Percentage of forest cover	Ratio/ Numeric	Data estimated by local village head and visually verified through satellite imagery
Matsutake production	Matsutake habitat area (rectified)	Numeric	If several villages shared the same harvesting area, the habitat area was rectified by dividing the total harvesting area by the no. of villages
	Matsutake habitat area/person	Numeric	
	Total production of Matsutake (rectified)	Numeric	Similar to indicator 11, total production was estimated at the market, the production of the village investigated was rectified by dividing the total production estimated at the market by the no. of villages
	Matsutake production/habitat area	Numeric	
	Harvesting production/capita	Numeric	
Livelihoods	Contribution of matsutake to cash income	Numeric	Percentage of household income

(con'd)

	Average cash income per capita	Numeric	
	Average agricultural landholding per capita	Numeric	
Labor input	Length of matustake harvesting season	Numeric	Total harvesting days
	Average travel time per harvesting trip	Numeric	Hours
Income	Average cash income per year per capita from matsutake	Numeric	Yuan
Market	Nearest market category	Category	1- County market, 2- Village market, 3- Floating market
	Degree to which information on pricing is accessible	Category	1- Well known (through mobile, transparent market), 2- Moderately known, 3- Poorly known
	Choice of and chance for selling	Category	1- Good (with more than five competitive buyers); 2- Moderate (with three to five buyers), 3- Poor (one or two buyers)
Harvesting behavior	No harvesting of <4–5 cm	Category	1- Restrictions implemented, 2- Moderately implemented, 3- Poorly implemented,
	Habitat management	Category	1- Good management (with site preparation, e.g., thinning, watering,), 2- Moderate management, 3- Poor management

the classified patterns of each indicator. Kruskal-Wallis (for *n* independent samples) and Mann-Whitney U (for two independent samples) were used for significance testing (significance level $p < 0.05$). In addition, we evaluated the equity of resource use, benefit-sharing mechanisms, and the relationships among resource users, factors that have generally been ignored by other authors. Despite the fact that these variables were assessed in a descriptive and subjective manner, the assessments were worthwhile because they approached management systems from an angle that could not be captured and interpreted by statistics.

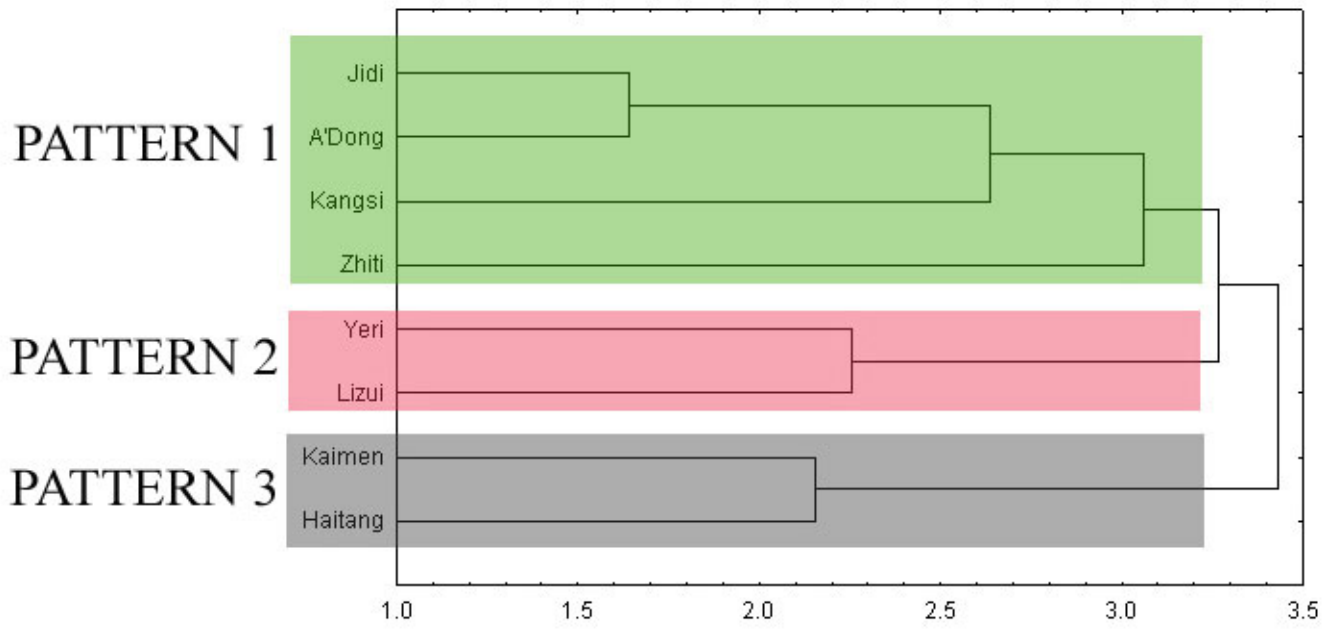
RESULTS

Patterns of Matsutake Management

We tested 21 different combinations of parameters and methods amongst which the output of clusters vary. The most frequent output (Fig. 3) was assessed against empirical observations and selected to represent the degrees of similarity and difference between management systems. By summarizing the major characteristics of each pattern, we interpreted them in relation to the system of resource access, and the degree of enforcement of regulations. In the eight communities, matsutake were accessed in two major ways, by common or private access. Common access operated at three levels: (1) common access within the community or communities in agreement, but excluding outsiders; (2) allowing outsiders access under certain conditions (generally by leasing user rights); and (3) open access for anybody. For instance, Jidi, Adong, and Zhiti fell into the first category because several villages share the harvesting rights to matsutake. Jidi village also issued permits to outsiders for designated forest plots each year and collected a harvesting fee. In Kangsi, matsutake sites were open to anyone, including outsiders.

During the field survey we found that communities throughout Yunnan, sometimes supported by external agencies, devised a diverse range of

Fig. 3. Diagram showing the clustering of eight cases.



management regulations for matsutake mushrooms and their habitats. In general, these regulations covered (1) boundary demarcation and terms of exclusion; (2) activities permitted within the matsutake habitat; (3) harvest timing and methods; (4) enforcing and monitoring regulations; (5) penalties; and (6) benefit distribution mechanisms. The main function of these management regulations was to control access to and harvesting of matsutake resources in order to ensure local incomes while also ensuring sustainable resource use. The regulations adopted varied among communities. Although most communities had matsutake-related regulations, some simply existed on paper. The capacity of local institutions to develop, enforce, and adapt these regulations to changing circumstances varied.

Pattern 1: Common access with loose enforcement of regulations

Among the eight communities, four were classified as Pattern 1, i.e., Jidi, Adong, Kangsi, and Zhiti, and two sub-classes could be identified (Fig.3). This implies that there are variations and differences even within a classified pattern. The key common characteristics of this type were: (1) common resource access and (2) regulations existing but loosely enforced or implemented.

Pattern 2: Common access with strong regulations

Yeri and Lizui fell into Pattern 2. Pattern 2 differed from Pattern 1 in terms of the degree to which regulations were enforced, with enforcement being relatively stronger under Pattern 2. Enforcement of regulations is a dynamic process subject to change in varying socioeconomic and ecological conditions. That is, a community may shift from Pattern 1 to Pattern 2 when favorable conditions are met, or in the reverse direction when certain conditions are no longer in existence. For instance, Jidi and A'dong used to have strong regulations, but due to the replacement of influential village leaders, the implementation of regulations deteriorated.

Pattern 3: Private access

Haitang and Kaimen were classified as Pattern 3. In contrast to other cases, they both implemented private resource access, but forest ownerships differed between the two communities. In Haitang, due to clear implementation of the forest tenure

reform policies (*lingye sanding* and *liangshan huafen*), parts of the collective forest were contracted to each household (*ziliushan*). Therefore, user rights over forests together with matsutake collection rights were given to individual households. In Kaimen, despite forest land being collectively owned, it had been contracted to households for a given period. The village committee delineates the forest into plots and leases out the harvesting rights either to individual households or to a group of households. The contractor can be an outsider, and this is decided through an open-bid process. The income from the contracting fee is redistributed to the whole village.

Performance of the Three Patterns

Comparative performance between patterns was analyzed through quantitative and descriptive measurements. Among the 14 variables tested, eight presented significant differences between patterns (see Fig. 4). We interpreted them in terms of productivity, income, harvesting behavior, labor inputs, and yield.

Matustake production was high in Diqing Prefecture, as were yields from harvesting (Fig. 4a). The average production was around 1.9 kg per household per day in Pattern 1, 0.6 kg in Pattern 2, and 1.1 kg in Pattern 3. Despite the fact that Pattern 1 is ecologically more productive (Fig. 4-a), it does not perform best in terms of household economy (as measured by household income from matsutake and matsutake income per capita, Fig. 4b, c). Instead, Pattern 3 appears to perform the best (Fig. 4b, c). This can be related to the quality of products provided, which in turn is affected by mushroom pickers' relationships, harvesting choice, and behavior. As shown in Fig. 4d, e, significant differences existed among harvesting preferences in respect to product size and quality. Mushroom pickers preferred to harvest large, high-grade matsutake in Haitang and Kaimeng (Pattern 3) and very few collected baby ones. In contrast, more baby mushrooms and fewer high-grade matsutake were harvested by mushroom pickers from Patterns 1 and 2 (Fig. 4d, e).

The explanation for this result may be related to the type of resource access. Under common access, community relationships among mushroom pickers are competitive, and skilled pickers have better knowledge about the ecological characteristics of mushroom spots. They know of more secret spots than others and tend to harvest better mushrooms, trying to protect those spots with a favorable environment as they perceived it. The others meanwhile depended mainly on luck and picked whatever they found in a day, most frequently smaller mushrooms. In contrast, harvesting access rights under Pattern 3 were private. The owner's priority for management was to avoid theft. Because there was no competition within each plot, all the mushroom spots were known and mushrooms were picked at the best time. Moreover, technologies were employed to improve quality; for instance, making a shelter to prevent attacks by insects and rodents. In terms of labor inputs, common-access mushroom pickers spend a long time each day (8–11 h) seeking mushrooms and traveling across wide areas (Fig. 4f), whereas private-access households spend only around fiv5e h per day but invest more labor in harvesting and site management (Fig. 4g). In many cases, temporary workers were hired.

Although not statistically significant, the percentage of income from matsutake showed a decreasing trend from Pattern 1 to Pattern 3 (Fig. 4h), indicating a greater dependence on matsutake in Pattern 3 cases (mainly in Diqing Prefecture) than elsewhere. Data concerning alternative cash income sources (Fig. 4i) revealed that households from Pattern 3 had other options for earning cash besides matsutake harvesting.

Factors Related to Income Generated from Matsutake

For each individual household or community, income generated from matsutake was the issue of greatest concern. Income generated from matsutake could be influenced by factors such as yield, socioeconomic status, management approaches, harvesting behavior, inputs, and marketing. In this analysis, however, high yields did not necessarily bring high income. Harvesting yields per person per year in Jidi were more than one and a half times those in Haitang and four times those in Kaimen, but income in Jidi was only half as high (see Table 4). This indicates that other factors, such as management, harvesting techniques, and marketing options, play more important roles than production itself in earning higher incomes.

Further analysis revealed that harvesting behavior and labor inputs were closely related to the income earned. The higher the grade of mushroom and the fewer baby mushrooms harvested, the greater the

Fig. 4. Differences between the three patterns at household level (a) income generated from matsutake; (b) per capita income from matsutake; (c) percentage of income from matsutake in total household cash income; (d) alternative sources of cash income; (e) percentage of high-grade matsutake harvested per household; (f) percentage of baby matsutake harvested per household; (g) number of pickers per family; (h) hours spent harvesting matsutake per day; (i) average number of kilograms harvested per day per household.

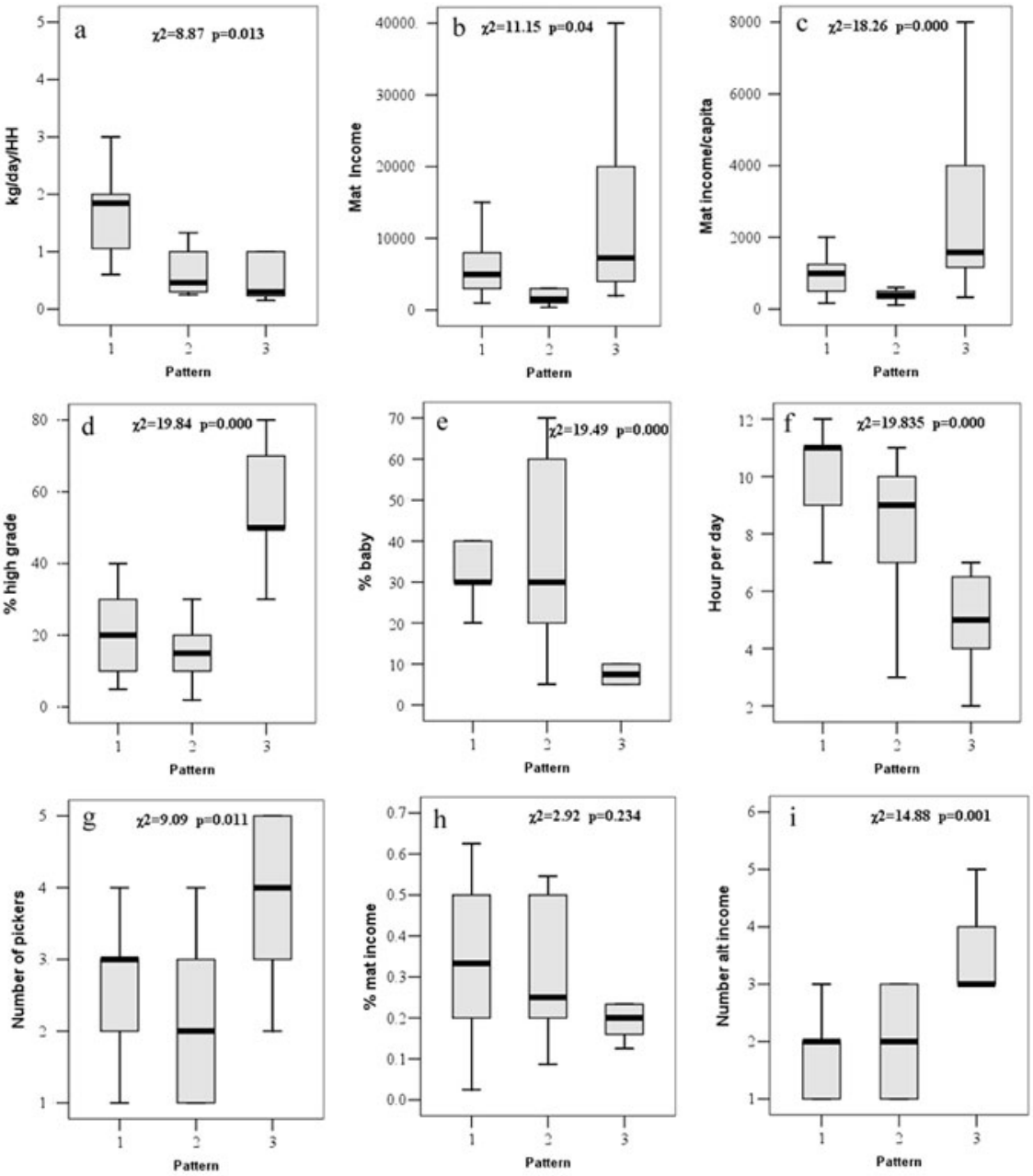


Table 4. Eight examples of matsutake production and income (US$1 = 6.8 CN Yuan).

Village	Pattern	Harvesting/capita/year(kg)	Matsutake income/capita/year(Yuan)
Jidi	1	30	1490
A'Dong	1	21.1	1480
Kangsi	1	3.9	572
Zhiti	1	2.8	738
Yeri	2	22.2	829
Lizui	2	2.8	422
Haitang	3	20	3300
Kaimen	3	6.7	2796

income generated (Fig. 5a, b). In private-access systems, nobody harvested baby matsutake: they left them to grow until the best market prices were available. Consequently, they earned more income in these systems than under the open-access systems where all the community members harvested baby mushrooms. Similarly, people who harvested mainly at their "secret/private site" earned more than those who did not (Fig. 5c).

More labor inputs resulted in higher earnings (Fig. 6a). Time spent per day harvesting, however, did not positively relate to high earnings (Fig. 6b). In open-access cases, people spent 10–12 h searching in the rugged mountains and traveling to market. In private-access systems, however, the location and growth status of each site was well known and monitored, so 4–6 h was sufficient for harvesting and site management.

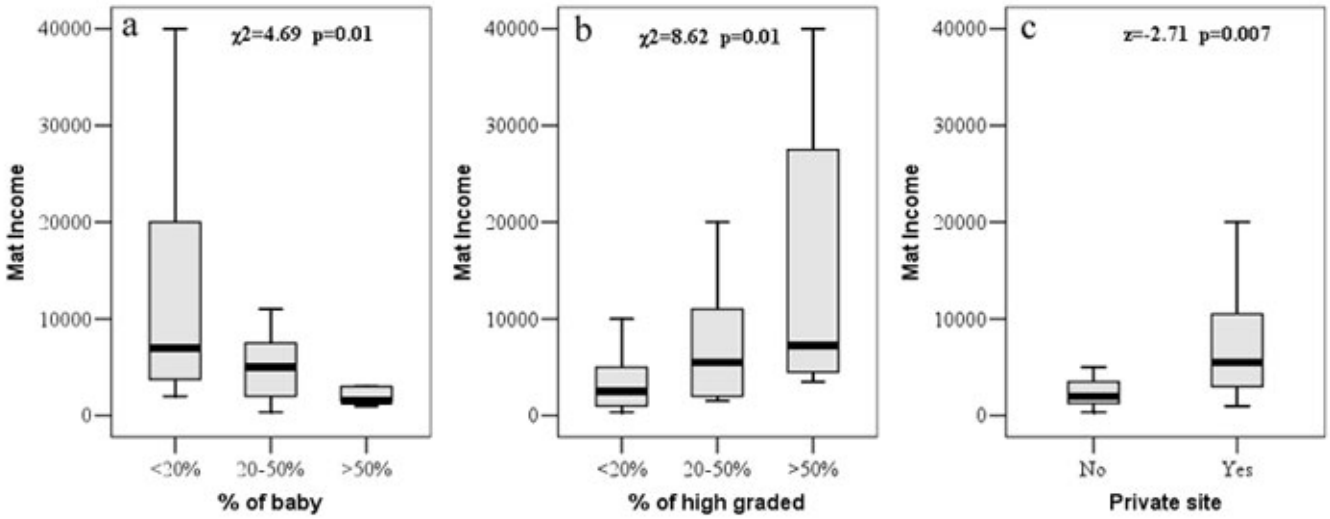
DISCUSSION

Factors Determining Matsutake Management Practices

Matsutake only became an important commercial product in Yunnan in the 1980s, before which it was not favored either for consumption locally or for sale. As demand for matsutake increased, it became necessary to introduce regulations and management practices to ensure the sustainability of resource use. Management practices ranged from systems with no or informal regulations to formal contracting systems. The regulations were enforced at varying level. What factors resulted in a community developing a particular management system rather than another? Examination of eight communities and their management practice systems suggests that forest policy, institutions, resource status, markets, geographical conditions, and outside interventions all played important roles.

First, policies—especially forest tenure arrangement—are important in shaping the context of matsutake mushroom management. The type of forest tenure determines resource access and harvesting behavior and incentives or disincentives for site management activities. When forestlands are common access, harvesters tend to be competitors as they extract the resource from the same pool. To earn more, one needs to extract more of the resource than others. Therefore, activities focus on keeping known, secluded sites secret and searching for new ones. Although everybody knows that much higher incomes accrue if matsutake is harvested at its best, few people wait once the mushrooms have emerged above ground because there is always the risk that

Fig. 5. Box plot showing harvesting behavior related to income generated.



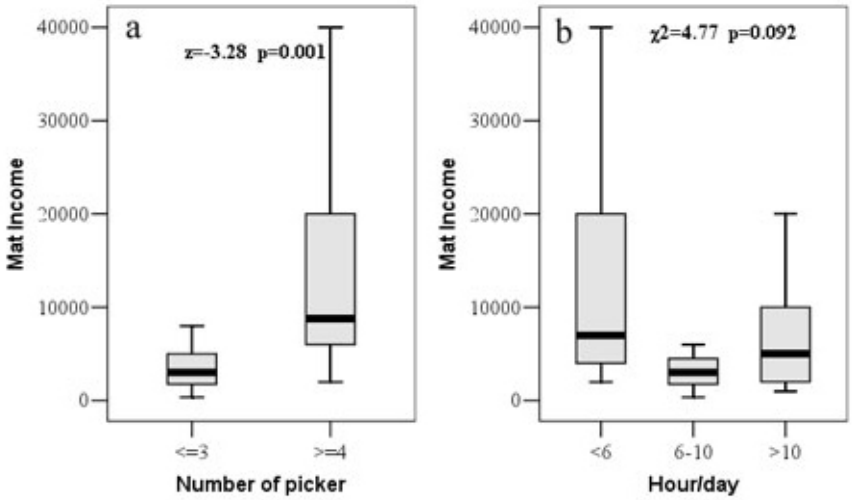
others will harvest them. With private access, no competition exists. The owners have an incentive to improve the quantity as well as the quality of mushrooms harvested, so site management (such as forest structuring and applying insect prevention nets) becomes an important concern.

Second, local institutions, including their capacity to develop and enforce management regulations, determine the effectiveness of management system. Given the ambiguous role of the local village committee in managing matsutake, in many cases facilitation in developing local institutions was provided by outsider agencies such as NGOs, research organizations, and government agencies. For instance, The Nature Conservancy (TNC) helped A'dong and Yeri formulate regulations; the contracting system of Kaimen was promoted by the Forest Bureau of Nanhua County; and Baimaxueshan Nature Reserve made great contributions to establishing regulations and providing monitoring for Yeri village. Experiences from several of these sites showed, however, that local institutional capacity is important for the long-term implementation of regulations. In some cases, changes in leadership appeared to lead to a decline in the implementation of management regulations, suggesting that continued implementation depends on the leadership of village heads.

Third, the resource status, especially stock, may be associated with the resource management measures taken. When the resource stock is small but valuable, people care more about its sustainability. In the 1980s, Chuxiong Prefecture was very productive and was the most important place for export of matsutake, with an estimated production of 1000 metric tonnes. It then underwent a resource depletion period due to overharvesting, and production dropped abruptly. A similar situation could take place in Diqing Prefecture where stock is still abundant. Although worries and awareness of resource decreases have caught the attention of local communities, few effective actions and measures have been taken yet to protect these resources.

Fourth, topographic complexity may indirectly affect the management approach selected. In Deqin County, the rugged complex physical environment was recognized by the local communities as the key impediment to applying effective alternatives to common access. The inaccessible landscape makes stringent management costly and gives rise to uneven physical distribution of resources, and consequently raises the difficulty of resource tenure division. For this reason, many communities structured resource access along the lines of traditional access systems. Other physical site features, such as remoteness, also determine the

Fig. 6. Box plot showing labor input related to income generated.



level of difficulty in excluding other communities from access, and thus influence the transaction costs involved in enforcing tenure rights. This was recognized by Cinner et al. (2006) in the case of fishery management in Papua New Guinea and Indonesia, where periodic closures as an adaptive management practice were made possible in remote communities.

In addition, the market environment also exerts impacts on enforcement of regulations. The acceptance of baby mushrooms by the market renders local regulations prohibiting collection ineffective. Another aspect of institutional arrangements that has been insufficiently studied is the costs incurred under different management systems. Anderies et al. (2004) noted that transaction costs of operation and collective action in developing, monitoring, and enforcing rules are important in determining the success of certain management strategies. This applied in the case of Lizui, where the collective harvesting, marketing, and benefit distribution system was highly regarded by villagers in 2006. This was not able to continue, however, because matsutake production dropped in 2007 as a result of extreme climate variation. We suspect that the operational costs (payments for the management team, mushroom pickers, and household shares) exceeded the net gains from implementing the system. This issue should be researched more thoroughly in future.

Dynamics in Management Practice Systems

Managing natural resources is never a static task (van der Brugge and van Raak 2007). It evolves as a flexible response to changing biophysical and socioeconomic conditions. When certain conditions change, the management system can also change. Jidi, A'dong, and Kangsi used to have strong institutions and regulations, but no longer apply them. In Kangsi, for the purpose of promoting yields, forest enclosure was attempted around 10 years ago for 5 d during which nobody was allowed to harvest. This system failed because after 5 d of enclosure, all the mushrooms emerged above ground and secret or private sites were exposed to everybody. Some sites were even destroyed. Thus, nobody supported the village committee again in the management of matsutake, and the management system reverted to the free harvesting system that operates to date. Jidi also made attempts to improve management. In the beginning, they arranged for forest guards to patrol, and then invented a rotational harvesting system (dividing the forest into plots and villagers into groups, rotating the groups to harvest at different plots on different days) but, following a subsequent change in village leadership, this system collapsed. With help from The Nature Conservancy (TNC), A'dong set up a rest-day system in which the village was not allowed to harvest on 1 d each week, with inspectors checking households for mushrooms harvested on the rest day. In the

beginning, this regulation was welcomed by villagers because it gave them a chance to do farming and look after their livestock. It was not continued, however, because villagers found that neighboring communities were illegally harvesting on the rest day, and this was difficult to monitor and control. In addition, in order to prohibit the harvesting of baby mushrooms, inspectors also monitored sales at the local market. When the rule was violated, a fine was levied. In the case of Jidi, however, the system almost broke down when the village leadership changed. In Lizui, facilitated by TNC, a system of collective and centralized harvesting, marketing, and benefit distribution was established in 2006. Villagers were divided into specialized work groups: forest guards, mushroom pickers, and a management team with the responsibility of guiding the whole process, including decision making, marketing, monitoring, and benefit distribution. Forests were divided into plots and mushroom pickers into groups. By drawing lots, mushroom pickers could only harvest inside the designated plot. The mushrooms were weighed and valued and handed in to the management team. Mushroom pickers were paid 30% of the total value harvested. The rest of the income was divided into two parts: one part was redistributed to each household and the other used to remunerate the management team and forest guards. In all other communities studied, harvesting was carried out with the household as the basic unit, but this arrangement in Lizui was collective, i.e., collaboration between households, rather than competition. This system, however, was only tested for 1 year and then abandoned.

Collective Forest Tenure Reform—Opportunity or Challenge?

Although we have shown that among these eight cases, private access provides the highest economic returns in a sustainable manner, it does not follow that this system is widely applicable. Currently, a process of collective forest tenure reform is taking place under which collective forest user rights are being transferred to individual households (Xu and Jiang 2009). The implementation of this policy may eventually influence the matsutake management system. In the course of this research, a video was made to demonstrate different management systems. It was shown to several villages in Diqing Prefecture (e.g., Jidi, Jiangpo, A'dong, and Yeri) with the explicit purpose of promoting the private access model, which we thought would provide an opportunity for managing matsutake sustainably with better returns. To our surprise, although viewers in every village appreciated the effectiveness of the contracting system, they did not think that it was the best approach for their community. The most frequently mentioned problems were: (1) large forest land areas are difficult for individual households to manage; (2) uneven resource distribution causes problems for plot division and household allocation; and (3) social conflicts may arise when dividing the forest lands. The root causes of these problems are uneven spatial resource distribution, management costs, and equity issues, all of which present challenges to privatization. In the process of privatization, considerable efforts would have to be expended to solve conflicts and balance interests. Villagers interviewed did not welcome a resource demarcation and distribution process that might destroy the equal access opportunities that are currently enjoyed by each household. Similar concerns were raised by Adhikari et al. (2004) after analyzing the relationships between household characteristics and forest dependency in Nepal. Some households may receive less access to resources. This is especially the case for vulnerable groups in the community (Delang 2006, Kusters et al. 2006, Viet Quang and Nam Anh 2006). Even if the privatization process is smoothly implemented, in the mountainous areas of Diqing Prefecture it is not easy for an individual household to take care of forest resources located 4–5 h walk away from their residence. Effective management would incur much greater transaction costs. By comparison, common access minimizes the problem of uneven resource distribution, providing maximum equity of access to the resource at low management cost (Pretty 2003). Moreover, in remote villages with few cash income-generation opportunities, villagers are highly dependent on each other to ensure many aspects of their livelihoods, so they are more likely to prefer to retain their rights to community resources rather than demand a shift to a privatized tenure or access system (Ruttan 1998).

Conditions for Sound Management Practices

Both private and common access have strengths and disadvantages. Which strategy a community develops and evolves depends on site-specific socioeconomic and ecological conditions. To manage matsutake effectively at the community level, the key is a well-functioning institution. A good institution, which is practical, flexible, and

adaptive, can provide mechanisms for equitable resource access and benefit sharing and ecological management. Such an institution is flexible in its responses to changing environments and markets (Olsson et al. 2004). Importantly, the enforcement of regulations should be carried out at reasonable cost. Generally the community committee is the default institution responsible for managing matsutake. Especially in the context of rapid social transformation in rural China (Xu et al. 2007), as committee members change over time, we frequently observe the relatively weak enforcement of regulations established by former committees. In this context, an independent institutional instrument, for instance, a matsutake management association, may be an alternative. Such an institution should have stable leadership and be capable of maintaining a good relationship with community committees. It should also have the power to negotiate a good price from markets. Sustainable production and quality control should be its primary objectives.

The purpose of privatization is to decentralize natural resource governance and eventually provide incentives to local communities for improved forest management (Xu and Jiang 2009). The collective forest tenure reform for privatization might, however, encounter great challenge, in areas like Diqing Prefecture because of its high transaction costs. These costs include how to resolve the historically disputed areas that cross community boundaries and how to distribute unevenly shared resources to households at the individual level. Personal communication with government officials in charge of forest tenure reform in Diqing Prefecture revealed that allocating forest patches to each individual household is not applicable, as it may give rise to social conflicts. Rather, the government prefers to keep the forest intact and assign shareholdings to each household. If such an approach is adopted, common access will still continue. In addition, the external interventions either from government agencies such as forestry or from environmental NGOs can help strengthen the functioning of local institutions relevant to adaptation to changing environment and conflict resolution over access to natural resources.

Communities having common access actually have profound knowledge and site-specific practices in matsutake management. For instance, Jidi village used to solve the problem of uneven resource distribution and maximize equity of resource access through a rotational harvesting system; Lizui developed a collective management practice and a sophisticated system for saving labor and sharing the benefit; A'dong and Yeri applied the rest-day system, which reduced the pressure of harvesting on resources. These practical innovations can trigger adaptive institutions. Optimizing these approaches may satisfy both economic and ecological requirements by meeting the diversity of interests and values in stakeholders (Hanna et al. 1995). This places great demands on both internal and external capabilities for strengthening local institutions, and it is critical to establish how different kinds of institutions—including village committees, government agencies, and NGOs—can support combinations of resource management practices and tenure arrangements.

CONCLUSION

A variety of matsutake management systems have arisen and evolved in the last two to three decades in Yunnan Province, China. With considerable biophysical and socioeconomic variation across the region, communities have developed different coping strategies customized to their own needs and socioeconomic and ecological settings. In general, there are three patterns of management: common access with loose enforcement of regulations (Pattern 1), common access with strong enforcement of regulations (Pattern 2), and private access (Pattern 3). Variations in institutions, including resource access and enforcement of regulations, result in different outcomes of management practices, income generation, and harvesting behavior among the three patterns. Private and common access both have strengths and disadvantages. Private access performs well in terms of household incomes, whereas common access provides community members with an equal opportunity to share the resource and reduce the management costs in areas with complex topographic conditions. The key to effective matsutake management is a dynamic functioning of institutions at the community level. Local knowledge, innovations, and practices for improving resource management should be understood, appreciated, and facilitated with support from external interventions for coping with changes. State policies, such as collective forest tenure reform, should be implemented in a flexible and adaptive manner given the complex biophysical environment and diverse and dynamic socioeconomic conditions.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol14/iss2/art30/responses/

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