Hum Ecol (2014) 42:481–491
DOI 10.1007/s10745-014-9650-z

Traditional Livelihoods, Conservation and Meadow Ecology in Jiuzhaigou National Park, Sichuan, China

Lauren Urgenson · Amanda H. Schmidt · Julie Combs · Stevan Harrell · Thomas Hinckley · Qingxia Yang · Ziyu Ma · Li Yongxian · Lü Hongliang · Andrew MacIver

Published online: 21 February 2014

Abstract Jiuzhaigou National Park (JNP) is a site of global conservation significance. Conservation policies in JNP include the implementation of two national reforestation programs to increase forest cover and the exclusion of local land-use. We use archaeological excavation, ethnographic interviews, remote sensing and vegetation surveys to examine the implications of these policies for non-forest, montane meadows. We find that Amdo Tibetan people cultivated the valley for >2,000 years, creating and maintaining meadows through land clearing, burning and grazing. Meadows served as sites for gathering plants and mushrooms and over 40 % of contemporary species are ethnobotanically useful. Remote sensing analyses indicate a substantial (69.6 %) decline in meadow area between 1974 and 2004. Respondents report a loss of their "true history" and connections to the past associated with loss of meadows. Conservation policies intended to preserve biodiversity are unintentionally contributing to the loss of these ecologically and culturally significant meadow habitats.

Keywords Cultural landscape · China's forest policy · Ethnobotany · Nature reserves · Meadow loss

L. Urgenson (✉) · S. Harrell · T. Hinckley
School of Environmental and Forest Sciences,
College of the Environment, University of Washington,
Seattle, WA 98195-2100, USA
e-mail: lsu@uw.edu

A. H. Schmidt
Geology Department, Oberlin College, Oberlin, OH 44074, USA

J. Combs
UW Botanic Gardens, University of Washington, Box 354115,
Seattle, WA 98195-4115, USA

S. Harrell
Department of Anthropology, University of Washington, Box
353100, Seattle, WA 98195-3100, USA

Q. Yang
Science Department, Jiuzhaigou National Park, Aba Prefecture,
Sichuan Province, China

Z. Ma
Department of Bioscience, Ecoinformatics and Biodiversity, Aarhus
University, Building 1540, Room 318, 8000 Aarhus C, Denmark

L. Yongxian · L. Hongliang
Department of Archaeology, Sichuan University, 24 S Section One,
Yihuan Road, Chengdu, 610065 Sichuan, China

A. MacIver
Division of the Social Sciences, University of Chicago, 5828 South
University Avenue, Pick Hall 301, Chicago, IL 60637, USA

Introduction

Despite international recognition that biodiversity conservation should respect and account for indigenous cultures (Phillips 2003; Xu and Melick 2007), the role of human land-uses in preserving ecosystems is a subject of debate, with practical implications for management of protected areas (McShane *et al*. 2011; Miller *et al*. 2011). On one side, land-use is viewed as outside the natural range of variability and thus detrimental to biodiversity conservation (Wells *et al.* 1992; Terborgh 2004). On the other side, landscapes are portrayed as products of human-environment interactions and human disturbance as potentially beneficial to biodiversity (Phillips 1998; Peña 1999). In reality, the extent to which land-use either aids or inhibits conservation depends on the nature and extent of human activities and their historic role in shaping the distributions of species and habitats. Understanding these linkages allows us to evaluate conservation practices critically and to formulate management policies that support biological diversity and local cultures.

Jiuzhaigou National Park (JNP) presents an illustrative instance to examine the linkages between human land-use and ecosystem conservation. JNP is a UNESCO World Heritage Site and Man and Biosphere Reserve located in the headwaters of the Yangtze River in Sichuan Province, China. The Park is renowned for tufa-formed lakes and waterfalls, rich biological diversity and the local Amdo Tibetan culture (Liu 2007). "Jiuzhaigou" means "nine-village-valley" in reference to the historic Tibetan villages in the area.

Traditional land-use in JNP included rotational agriculture, animal husbandry, preservation of sacred sites, and harvest of timber and medicinal plant resources (Winkler 1998a; Henck *et al*. 2010). These practices may have influenced patterns of diversity at species, community and landscape scales (Kimmerer and Lake 2001). Studies from the region suggest that meadows, in particular, are linked to indigenous activity (Winkler 1998a, b) and thus may be particularly sensitive to changes in land-use. Due to a lack of information on the historic roles of humans in the landscape, programs intended to conserve biodiversity in JNP may be leading to the loss of these meadow habitats.

Current conservation policies in JNP focus on increasing forest cover by "protecting existing forest resources and restoring plant cover to lands that were originally deforested in order to protect the development of biological diversity" (Liao *et al.* 2009). In accordance with these goals, the Park administration has undertaken two approaches. First, since 1992 management has progressively transferred local residents from employment in agriculture and animal husbandry to tourism and environmental conservation. Beginning in 1996, a 5-year plan was implemented to reduce agricultural and pasture land in the Park. Local residents have been prohibited from farming, grazing, or firewood gathering since 2000 and grazing animals (yaks, sheep, and cattle) were officially removed in 2002.

Second, Park authorities use funds from China's two large-scale reforestation programs—the Returning Farmland to Forest Program (RFFP; also known as "Grain-to-Green" or "Sloping Land Conversion Program") and the Natural Forest Protection Program (NFPP)—to plant trees in areas previously used for farming and grazing. Initiated in 1998–2000, these programs direct the restoration and protection of forest cover in headwater regions of major river systems through a ban on logging, conversion of steep slopes from agricultural croplands to forestland, tree planting campaigns, and compensation of farmers for economic losses due to cessation of farming or grazing (Wenhua 2004; Xu *et al.* 2006; Schmidt *et al.* 2011; Trac *et al*. 2013). The large scale and potential ecological benefits of these programs have drawn international praise (Zhang *et al.* 2000; Tallis *et al*. 2008).

The programs have also received criticism for taking an overly uniform approach to implementation, and for giving insufficient consideration to the ecological and economic functions of grasslands and the resource needs of local communities (Xu *et al*. 2006; Trac *et al*. 2007; Bennett 2008; Urgenson *et al*. 2010; Robbins and Harrell 2014). In Jiuzhaigou, tree-planting was mandated on all slopes steeper than 8 %, and 400 hectares are reported to have been reforested by 2008 in accordance with these policies (Liao *et al*. 2009).

Extensive forestation overlooks the potential importance of montane meadows in maintaining species diversity and ecosystem services (Miller *et al.* 2003; Baur *et al*. 2006; Wu *et al*. 2009), and as sites for traditional cultural practices (Deur and Turner 2005; Brandt *et al*. 2013). How these factors operate in JNP is not well understood. There is strong need to examine the ecology, history, and human use of the meadow communities in JNP before remnants of these systems are gone. Here we present an integrated interdisciplinary examination of long-term human-ecological interactions in the montane meadows of JNP. We draw from archaeological data, ethnographic interviews, remote sensing and vegetation surveys to address the following questions:

1) What was the role of traditional human land-use in the creation and maintenance of montane meadows in JNP?
2) What ecosystem service benefits do montane meadows in JNP provide?
3) Has the meadow area in JNP changed since Park establishment and the implementation of reforestation policies and if so, to what extent?

Study Area

JNP is a 728 km^2 forested catchment located in the Min Mountain range (1,996–4,764 m elev.) on the northeastern rim of the Tibetan Plateau (Fig. 1). As a site of natural, cultural and scenic significance, Jiuzhaigou receives nearly 3 million tourists a year. Temperate coniferous, broadleaved, and mixed forest communities predominate below tree-line (~ 3,800 m) and are interspersed with shrub land and meadows (Winkler 1998b; Liu *et al*. 2007). The lower montane forest zone (2,000–2,400 m) is dominated by pine–oak forests (*Pinus tabulaeformis*, *Pinus armandii*, *Quercus liotungensis, Quercus aliena,* and *Quercus baronii*), with remnant patches of former hemlock forest (*Tsuga chinensis*) in shaded sites. Spruce-fir forests (*Picea wilsonii*, *Picea asperata, Abies ernestii,* and *Abies faxoniana*) dominate the upper montane forest (2,400–3,500 m), often inter-mixed with birch (*Betula utilis, B. platyphylla, B. albo-sinensis*) and poplar (*Populus davidiana, Populus rotundifolia*). In the sub-alpine zone (3,500–3,800 m), shady slopes support *Abies faxoniana* and *Betula utilis* in the sub-canopy; sunny slopes are dominated by juniper (*Juniperus convallium*) and by larch (*Larix potaninii*). In accordance with reforestation programs, abandoned agricultural fields, meadows, and other non-forest habitats throughout JNP have been artificially vegetated with seedlings of spruce (*Picea purpurea*) and pine (*Pinus*

tabulaeformis). Previous research suggests that meadow communities distributed below tree-line were historically maintained through periodic disturbances that prevented tree encroachment, including forest fire (Winkler 1998a) and grazing (Winkler 1998a, b; Henck *et al*. 2010).

According to current understanding, we can divide land-use history in JNP into five periods: (i) traditional agriculture and animal husbandry (until the early twentieth century), (ii) forest land conversion to growing opium (until early 1950s), (iii) collective agriculture combined with intensive logging and resource extraction during Maoist socialism (1950s–1970s), (iv) modified family-based agriculture and protected area establishment during the early Reforms (1979–1999), and (v) curtailed indigenous land-use and the implementation of forestation programs (1999-present). JNP was designated a nature reserve in 1979, opened to public tourism in 1984, and designated a UNESCO World Heritage Site in 1992. In 2013, there are six extant villages in JNP: Heye, Shuzheng and Zhechawa in the main valley of the Park; Jianpan and Panya in the Heye Valley; and Rexi in the Zharu Valley (Fig. 1).

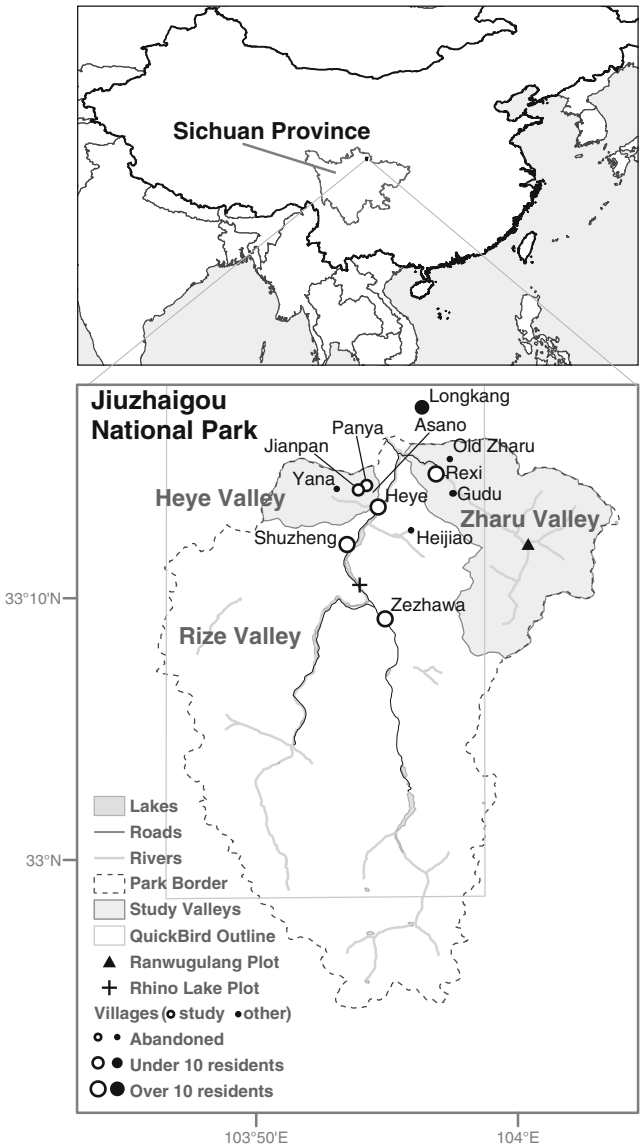

Fig. 1 JNP in Sichuan Province (*top*) and study sites within JNP (*bottom*). The footprint of the Quickbird image (used for remote sensing analyses) is shown in a *grey box* on the lower panel

Methods

Vegetation surveys were conducted at Rhino Lake (103.89°E, 33.18°N; 2,290 m) and Ranwugulang (104.00°E, 33.20°N; 2,570 m) meadows (Fig. 1). These meadows were historically cleared for farmland. Rhino Lake was cultivated by two families prior to the collectivization period. During collectivization, an additional area was cleared at Rhino Lake to accommodate agricultural expansion. The farmland remained in active use until Park establishment. Rhino Lake was planted with *Picea purpurea* seedlings as part of the NFPP program. Ranwugulang meadow was abandoned as farmland prior to the collectivization period and subsequently used for seasonal grazing of yaks and cattle. Ranwugulang is currently managed by the Park as an ecotourism site and, unlike Rhino Lake, was not actively planted as part of the forestation policies. Archaeological field surveys and excavations were conducted at Yana (103.89°E, 33.24°N; 2,680 m) and Asano (103.90°E, 33.24°N; 2,530 m) meadows (Fig. 1).

Data Collection

Archaeological Excavation

Archaeological field surveys were used to investigate the role of traditional human land-use in the creation and maintenance of montane meadows in JNP (question 1). We selected the Asano and Yana sites for surface surveys based on previous discovery of charcoal, radiocarbon dated as early as 2200 ybp. Between May 3 and August 24, 2008, field surveys and excavations were conducted at Asano and Yana meadows (Fig. 1). At the Asano site near Jianpan Village, a site was selected for excavation based on surface observations that indicated probable presence of an earlier dwelling. A 9×7-meter rectangular pit was excavated on the edge of a terrace to a depth of 7 m, 440 cubic meters of soil was removed, exposing 12 temporal layers and revealing two rooms of an ancient structure along with the contents of a storage pit in one of the rooms. In addition, several exploratory soil pits were dug at both Asano and Yana sites, to depths of 1 m.

Preliminary analysis of excavated artifacts was performed in-situ. Recovered charcoal, artifacts, and faunal remains were subsequently transported to laboratories at Sichuan University, Chengdu and the University of Washington, Seattle, for analysis, including typological dating of artifacts and detailed counts of animal bones. Charcoal was radiocarbon dated at

Beta Analytic Laboratories (Miami, FL, USA). Optically stimulated luminescence and thermoluminiscence analyses were completed at the University of Washington Luminescence lab.

Ethnohistorical Interviews

We interviewed Park residents in their homes in 2007, 2008, and 2011, and followed them in guided walks through neighboring meadow sites. Interviews were semi-structured based on a pre-determined set of questions. Topics included the ecological and cultural values of meadows, processes and practices that created and maintained existing meadows, and the gathering and use of meadow plant species. We purposely selected one to five elders in each of the six extant villages to participate in the interviews. Participants were selected based on their availability and recollection of historic land-use activity. Interviews were conducted in the local Tibetan language or in Mandarin Chinese; responses were hand-recorded and translated into Chinese and English for analysis.

Vegetation Sampling

We established vegetation monitoring plots within Rhino Lake and Ranwugulang meadows (Fig. 1) to document vegetation composition (question 2) and forest encroachment within meadow habitats (question 3). Plots were established in June 10–13, 2007 and re-measured September 13–15, 2011. Plot locations were selected to represent an area that had been intentionally planted with tree seedlings and one that had not.

We used a modified-Whittaker plot methodology (Stohlgren *et al.* 1995) to quantify the composition and diversity of meadow species. The modified-Whittaker is a 20×50 m plot with ten 0.5×2 m (1 m^2) subplots, two 2×5 m (10 m^2) subplots and a 5×20 m (100 m^2) central subplot. We measured mean herbaceous richness and species cover (%) in ten 0.5×2 m subplots and density of tree and shrub species in the 100 m^2 central subplot. We estimated herbaceous cover using a cover class scale (1=0–1 %, 2=1–5 %, 3=5–15 %, 4=25–50 %, 5=50–75 %, 6=75–95 %, 7=95–100 %). We tallied species presence in the rest of the plot. We identified species to the lowest taxonomic unit possible. In 2011, we collected data on height and branch growth for trees in the 100 m^2 central subplot. Annual height and branch increments were measured on individual trees to determine patterns in growth over time. From these and the density data, we were able to calculate changes in tree crown cross-sectional area at 0.5 m per hectare (we assumed that most herbs, grasses and forbs were below this height), thus providing another estimate of changes in meadow occupancy. Shrub volume was not calculated.

Remote Sensing

We used two remote sensing images, separated by 31 years, to examine changes in meadow extent at the Park and valley scales (question 3). The first is a 6–8 m resolution black-and-white KH-9 Mapping System image taken 31 December 1973. The second is a color 0.6 m resolution Quickbird image taken 27 November 2004. We completed the remote sensing analysis for the entire study area as well as for just the Zharu and Heye Valleys (Fig. 1). The valley sub-areas were defined using ArcGIS (Fig. 1, bottom). Analysis was limited to areas within the Park, contained in both images, and located below 3,800 m (the approximate level of the tree line in this region), totaling 399 km^2 for the entire study area (Fig. 1). A 218 km^2 section of the Park is not contained in the Quickbird image and thus was excluded from the analysis.

Mapping was completed by hand due to difficulty setting up an accurate, automatic reclassification scheme for both multi-band and panchromatic images. We defined meadows as areas with relatively smooth textures and light vegetation in the Quickbird image or as light grey to white areas in the KH-9 image, respectively. We calculated total meadow area within the Park and within Zharu and Heye Valleys to determine the change in meadow area between 1973 and 2004 from the two images. Ground truthing the Quickbird classification was completed in 2010.

Surface Mapping

We conducted surface mapping to examine local-scale changes in the perimeter of Ranwugulang meadow (question 3) between 2007, 2010, and 2011 (Fig. 1) using a handheld Trimble GPS. We defined the meadow perimeter as the border between areas with predominately (>50% cover) herbaceous vegetation and those with predominately trees.

Results

Question 1: Indigenous Land-Use

Interviews indicate that people intentionally created and maintained meadows prior to collectivization. Each family had a small property on which they lived and farmed. For example, a family of eight in Heye Valley owned 60 mu (4 ha) of land. Crops included oats, corn, buckwheat, wheat, and barley. To create croplands in forested areas people cut trees, piled and burned them. In non-forest areas, the soil was turned over and the surface burned to increase fertility. The importance of this land-use practice for people's livelihoods is evident in the name for one of the main valleys in the Park – Zharu Valley (Fig. 1). The word Zharu is based on the Tibetan "tsiyua" meaning "used to be forest and then cut trees, burned trees, and cultivated

land to grow crops". If there was tree encroachment they would burn again—resulting in a rotation system of burn, farm, graze and then maybe re-burn. Each patch of land had two planting seasons—fall (October) and spring (March). In the early twentieth century, areas around Zharu Valley, and perhaps to a lesser extent around Zechawa Village, were cultivated to grow opium. The nearby city of Songpan was a main opium market in southwest China (Nyima and Tian 2011) and according to local people opium was an important source of income in the valley prior to collectivization. During the collectivization period, opium agriculture ceased throughout Jiuzhaigou and some farming areas were abandoned. Meadows were also used as pastures to graze animals including cattle, yaks, and sheep. Meadows were not created specifically for grazing animals. Rather, animals were grazed in abandoned farmlands and in active farmlands between crops. The yaks often stayed at higher elevations but the cattle overwintered closer to the villages at lower elevations. The meadow areas were also important sites for gathering plants and mushrooms. According to women living in Heye and Rexi Villages, when open lands were not being used for growing crops they would visit the areas to collect medicinal herbs to sell at market. Their family income was dependent on selling herbs.

During the collectivization period households were concentrated in villages close to roads and near the valley bottoms. Some of the farmlands in Zharu valley, farther from roads, and higher in elevation were abandoned at that time, while additional farmlands were created in and around centers of concentration. Many of the remaining farmlands were cultivated continuously until the Restoring Farmland to Forest Program prohibited all farming in 1999.

Evidence from the archaeological investigation suggests anthropogenic activity has been ongoing for 2,000–2,200 years in Jiuzhaigou. Four samples of charcoal recovered from the Asano site were radiocarbon-dated at 2,000–2,200 years before the present (200 BCE-0 CE). Thermoluminescence dating of nine pot sherds and optically-stimulated luminescence dating of one sherd yielded similar dates. In addition, stylistic analysis of several hundred pottery sherds from the excavation site dates habitation to the Western Han dynasty (221 BCE-9 CE). Thus, it is clear from physical and cultural data that the house excavated at Asano was inhabited approximately 2,000 years ago. Whether settlements have been *continuously* inhabited since that time will require further research. However, specimens of pottery excavated from the Asano site and collected on the surface near Zharu were dated on stylistic grounds to the Northern and Southern dynasties period (ca. 300–600 CE), suggesting that the area was not abandoned, and may have been continuously inhabited until the present.

The contents of the Asano site suggest that human land-use 2,000 years ago was similar in many ways to more recent usage prior to the establishment of JNP. For example, the ancient structures housing the charcoal samples were aligned in rows along the faces of the terraces facing outward, in a manner similar to the placement of houses in Old Zharu Village, inhabited until collectivization in the late 1950s. Artifacts found at the Asano site not only reveal its age, but also allow us to infer some specific forms of land-use. Excavated agricultural implements, including iron shovels and a sickle, are of types in widespread use in Northwestern China during the Han and subsequent periods; and sherds from what appear to be storage jars found in an underground pit may indicate that people were storing grain. Taken together, this evidence suggests the ancient indigenous inhabitants of JNP may have practiced a form of grain agriculture similar to that practiced until recently, with the exception that they had no corn or potatoes, both American crops introduced after the Columbian exchange. Charcoal pieces were observed throughout the excavated profile and in soil pits, suggesting a history of fire.

A large number (861) of animal bones were recovered from the site and analyzed for species, wear, and use. Bones of domesticated goats and cattle bore marks of cutting and burning, indicating that animals were butchered and cooked. In contrast, many of the cattle were old when they died, indicating they may have been work animals butchered only as they became too weak to work. Horses were also probably kept as work animals, as their teeth reveal they lived to old ages and there are no marks of butchery or cooking. Finally, bones of the common or ring-necked pheasant, *Phaisanus colchicus*, as well as other as-yet unidentified birds indicate hunting; these birds inhabit both forest and grassland habitats and can be flushed walking around abandoned agricultural fields to this day.

Question 2. Ecosystem Services Provided by Meadows

Vegetation surveys and ethnographic interviews suggest meadows provide a suite of ecosystem service benefits.

Biodiversity We identified 92 (in 2007) and 84 (in 2011) individual meadow species in Ranwugulang and Rhino Lake meadows, with 57 and 69 species, respectively, at Ranwugulang and 58 and 62 species, respectively, at Rhino Lake. Vegetation sampling was conducted in June of 2007 and September of 2011, thus variations in species richness were likely influenced by phenology. Dominant (% cover) species at Ranwugulang included *Poaceae* spp., *Gentiana macrophylla, Fragaria orientalis*, and *Halenia elliptica*. At Rhino Lake the dominant species included *Poaceae* spp., *Artemisia* spp., and *Anemone tomentosa.*

Local respondents identified 32 % of the meadow species as commonly gathered and used (Table 1). Another 14 % were not described in our interviews but have been identified in the literature as culturally important plants (Clark 1995; Kletter and Kriechbaum 2001; Yuthog Foundation for Tibetan Medicine). Women from Heye Village believed that the disturbance created in meadow areas gave rise to a higher

Table 1 List of locally useful species sampled in Ranwugulang and Rhino Lake meadows in 2007 and 2011

Species	Sample year	Reported[a]	Literature[b]	Use category
Aconitum sp.	2007		x	Med
Actium lappa	2007	x		AF
Adenophora sp (incl. stricta)	2011	x		F, Med
Agrimonia pilosa	2011	x		Med
Allium sp. (incl. ovalifolium)	2011	x		F
Anaphalis sp.	2011	x		Med
Anemonae rivularis	2007, 2011		x	Med
Anemone tomentosa	2007, 2011	x	x	AF, Med
Apiaceae sp.	2007	x		MM
Arisaema sp.	2007	x		MM
Artemisia sp.	2007, 2011	x		Mat
Asteraceae	2007, 2011		x	Med
Berberis sp. 1	2007, 2011	x		Med
Berberis sp. 2	2007, 2011	x		Med
Bupleurum marginata	2011	x		MM
Cirsium sp.	2011	x		AF
Clematis sp.	2007, 2011		x	Med
Clinopodium polycephalum	2011	x		F, Med
Cotoneaster sp.	2007, 2011	x		Mat
Dipsacus sp.	2007, 2011		x	Med
Eleagnus sp.	2007		x	F
Fragaria sp. (incl orientalis)	2007, 2011	x		F
Galium aff boreale	2007, 2011		x	Med
Gentiana leucomalaena	2007, 2011		x	Med
Gentiana macrophylla	2007, 2011	x		Med
Hippophae	2007, 2011	x		F, Mat, Med
Hypericum sp.	2007, 2011		x	F, Med
Leontopodium	2001, 2011	x		Med
Lespedeza	2007	x		AF
Plantago sp.	2007, 2011	x		Med
Polygala sibirica	2007, 2011	x		F
Potentilla chinensis	2007, 2011	x		Med
Ranunculus japonicus	2007, 2011		x	Med
Ranunculus tanguticus	2007, 2011		x	Med
Rprunella vulgaris	2007, 2011		x	Med
Rubus sp.	2007	x		F
Salvia przewalskii	2011	x		F
Sedum aizoon	2007, 2011		x	Med
Silene fortunei	2007, 2011	x	x	Med
Taraxacum	2007, 2011	x		Med
Thalictrum uncatum	2007, 2011	x		F, Med
Thlaspi arvence	2007	x	x	Med

Use categories include *AF* animal feed, *F* food, *Mat* material use, *Med* medicine, *MM* medicine sold on market

[a] Reported indicates the use value was described during a local interview or meadow walk

[b] Literature indicates the species is listed as a medicinal in published resources (Kletter and Kriechbaum 2001; Clark 1995; Yuthog Foundation for Tibetan Medicine 2010)

diversity of species, including several useful plant and animal species. They noted declines in the abundance of medicinal herbs since harvesting and grazing were prohibited in the Park. These women reported increased dominance of species colonizing meadows including *Bupleurum* sp., *Gentianna macrophylla*, *Hippophae rhamnoides* and *Artemisia spp.* where a higher diversity of useful species were gathered in the past. *Pinellia ternata*, *Bupleurum* sp., and *Gentianna macrophylla* were described as useful medicinal plants historically collected between farming intervals. *Hippophae* and *Artemisia* spp. were not considered useful and were disliked.

Wildlife Several respondents associated loss of meadows in the Park with changes in wildlife abundance or distribution including declines in several pheasants, a hog badger (*Arctonyx collaris*), porcupines (*Hystrix brachyura hodgsoni*), and bears (*Ursus thibetanus and Ursus arctos*). Now that agriculture has ceased and meadows are perceived as declining, several respondents reported increased potential for human-wildlife conflicts. It was local tradition to give food leftovers, including crops, to wildlife. With the decline in agricultural fields and meadows, wildlife including porcupines and wild boars (*Sus scrofa*) turn to the villages to find food. Respondents reported feeling unsafe with increased wildlife in the village. They also reported that hungry boars dig up plant roots in the remaining meadows, contributing to declines in the diversity of meadow species.

Perceived Safety Several respondents reported the valley seemed "scary" when covered in forest. As one person described, "the forest is very dense and you cannot see around you so it does not feel safe". Several respondents also expressed concerns about perceived increased risk of forest fires associated with encroachment and increased fuel load, although they have not seen an uncontrolled fire in approximately 40 years.

Connections to the Past Respondents described the meadows as an important part of the true history of the valley and reported a loss of familiarity and connections to the past associated with loss of meadows. In the past, local people were familiar with places on the landscape, but now that the valley is becoming "all forest", several respondents did not feel they had "much knowledge of these places". With encroachment and growth of trees, the forest covers old houses and villages so local people cannot see or find the structures. According to one respondent, "[the Park] needs to keep track of the villages and their history; otherwise Jiuzhaigou will not be Jiuzhaigou. It's very important to keep this history."

Several interviewees expressed concerns that, with the loss of meadows, the younger generation will not see, and thus not know, their family history. Elders were concerned that the younger generations will not learn the traditional ways since they do not work in the fields. The loss of meadows also blurs property boundaries. People cannot discern each family's fields. As a result, respondents were concerned that the younger generation does not know their own family's farmland, "They just know the family house". Several elders reported that the younger generation does not believe them when they describe areas that used to be meadows and farmland.

A man from Shuzheng described a concern that "the true stories are being lost". He explained that the Park's tourist bus incorrectly describes the history of Rhino Lake meadow as shared grazing land when in fact it was a village's farmland. Two families farmed there, and the area contains a stone wall remaining from a historic home site. According to the man, "Now the Park is introducing the area as a grazing land. Why would anyone keep cattle in such a little place?"

Question 3. Changes in Meadow Area

Remote sensing, surface mapping, and vegetation surveys provided evidence for large declines in meadow area within JNP. Analysis of the 1973 KH-9 and 2004 Quickbird images showed a change in total meadow area from 20.87 km^2 to 6.35 km^2, indicating a 69.6 % decline in Park meadow area over this time period (Fig. 2). Similarly, meadow area declined from 2.73 to 1.15 km^2 in Heye valley and from 3.41 to 0.94 km^2 in Zharu Valley, a loss of 57.8 % and 72.4 %, respectively.

Surface mapping the perimeter of Ranwugulang meadow also illustrated high rates of meadow loss. In 2007 the meadow area was 0.030 km^2, in 2010 it was 0.024 km^2, and by 2011 it had had reduced in area to 0.022 km^2; a loss of 19 % in 4 years (Fig. 3). Vegetation surveys at Ranwugulang and Rhino Lake meadows revealed notable encroachment of tree and shrub species between 2007 and 2011. Tree density increased in both meadows but was greatest for Ranwugulang (1800 %) (Fig. 4b) largely due to the appearance of a large number of *Pinus tabulaeformis*. A relatively small increase in *Pinus, Picea*, and *Betula* seedlings and saplings (19.6 % total) was recorded at the Rhino Lake meadow. Shrub density increased in both meadows, and once again, the increase was greater for Ranwugulang (800 %) than Rhino Lake (15.6 %) (Fig. 4a). The combined tree and shrub densities in 2011 did not greatly differ between the two meadows, 1,280/ha and 1,120/ha for Rangwugulang and Rhino Lake, respectively. By 2011, tree crown cross-sectional area (at 0.5 m height) for Ranwugulang was almost 10 % of the measured meadow area. For the Rhino Lake meadow crown cross-sectional area was 1,370 m^2/hectare or about 14 % of the entire measured area (Fig. 4c). In 2007, tree heights in Ranguluwang for all species were less than 0.5 m; in 2011, heights were 3.3, 1.7, 1.4 m for *Betula*, *Pinus*, and *Picea*, respectively. For Rhino Lake meadow, *Picea* and *Pinus* tree heights averaged ~0.7 and 0.6 m in 2007; in late 2011, these two species averaged more than 2.1 and 1.8 m, respectively. Data for height versus tree age (not shown) suggest trees were entering a period of rapid height growth (increments between 0.3 and 0.8 m per year).

Discussion

Based on ethnographic interviews we conclude that, prior to Park establishment, human agricultural and husbandry practices created and maintained meadow habitats in Jiuzhaigou. Forests were cleared and the slash was piled and burned to create croplands. Yaks and cattle were grazed in abandoned farmlands

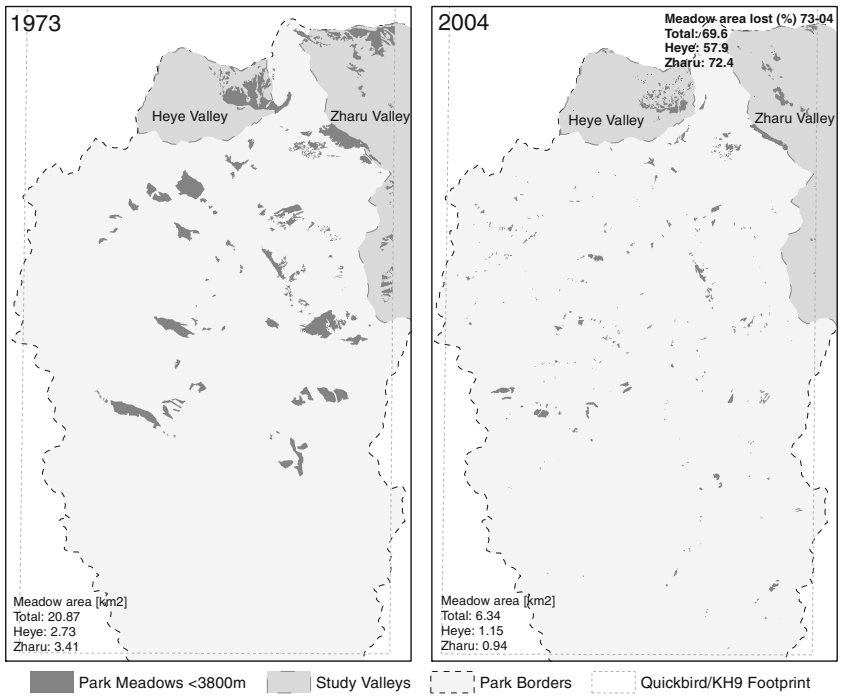

Fig. 2 The decline in meadows from 1973 to 2004 based on hand-mapped satellite images from the KH-9 and Quickbird satellites, respectively

and in active farmlands between crop rotations. If there was tree encroachment, they would burn again—resulting in a rotation system of burn, farm, graze and re-burn. These cleared areas were also important sites for gathering plants and mushrooms for food and medicine, key sources of income for some families.

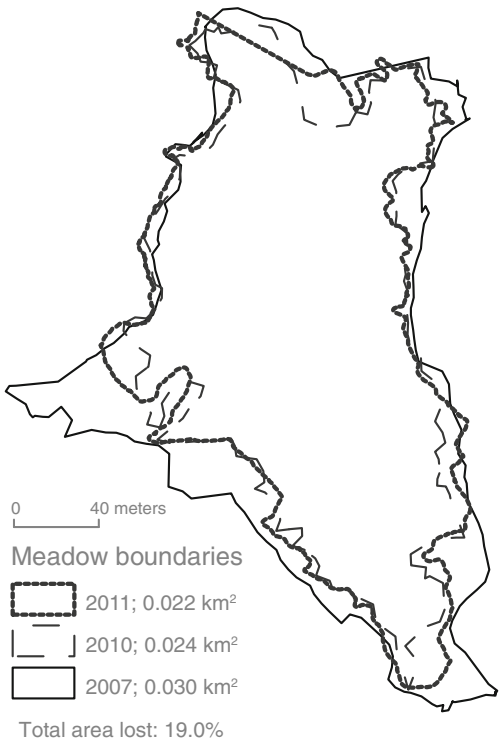

Fig. 3 Meadow encroachment at the Ranwugulang Meadow between 2007 and 2011

Archaeological evidence suggests that human habitation and its accompanying interventions have been part of the "natural condition" in Jiuzhaigou for at least 2,200 years. Uncovered features and artifacts indicate that historic practices of living, cultivating, and keeping domestic animals were similar in many ways to more recent usage prior to Park establishment.

Together, these findings suggest that the landscape of JNP is a product of long-term human-ecosystem interactions. Human land-use may have enriched biodiversity and ecosystem services through the creation of meadow patches in a landscape dominated by forests (Whitehead *et al*. 2003; Jeanrenaud 2002). There is growing scientific consensus that landscape heterogeneity is an important component of maintaining species diversity and ecosystem resilience (Gunderson and Holling 2002; Bengtsson *et al.* 2003), and that absence of local land-use and anthropogenic disturbances (i.e., forest cutting and burning) can result in ecological simplification with detrimental consequences for the conservation of biodiversity (Balmer and Erhardt 2000; Motzkin and Foster 2002). However, the extent to which indigenous peoples shaped contemporary landscapes and biota remains a contentious issue, and integration of these practices into the management of protected areas has been difficult (Foster *et al*. 2003; Whitehead *et al*. 2003).

Meadow habitats host high herbaceous species richness, with over 40 % reported to have a cultural use. Local people described the value of meadows for wildlife habitat, perceived safety, connections to their cultural heritage, and aesthetics. Several of these values have been ascribed to anthropogenic montane meadows in the U.S. and Europe where large-scale

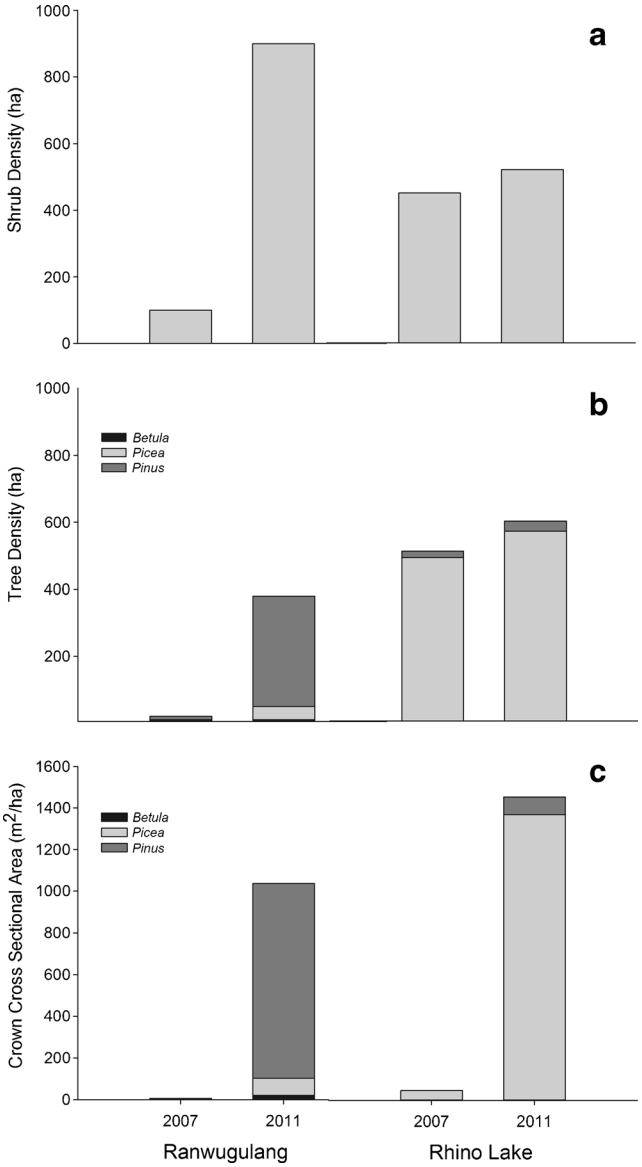

Fig. 4 Density of shrubs and trees and the crown cross-sectional area of tree crowns (measured at 0.5 m above ground) for early June 2007 and early September 2011 at Ranwugulang and Rhino Lake meadows

meadow restoration efforts are ongoing (Pärtel *et al.* 1998; Schulz and Crone 1998; Lett and Knapp 2005; Hellström *et al.* 2003; Halpern *et al.* 2012). Fortunately, in JNP there is an opportunity to actively manage for the conservation of meadow habitats while remnants of these systems still exist and there is a living memory of indigenous land-use practices.

Remote sensing analysis and surface mapping demonstrate a substantial decline in meadow area within JNP. Remote sensing surveys indicated a 69.6 % decline in meadow area over the 30 year period analyzed. Meadows within Heye and Zharu Valleys declined by 57.8 % and 72.4 %, respectively. Surface mapping the perimeter of Ranwugulang meadow revealed a 19 % loss in meadow area between 2007 and 2011, suggesting a portion of meadow loss is due to encroachment of trees inward from the margin. Some meadow loss would be expected in the remote sensing analysis since the 1973 KH-9 image was taken during a period of agricultural expansion. Large scale timber harvest was also taking place at that time, but in areas located farther south (upstream) in Rize Valley (Fig. 1), whereas the meadows occurred primarily in the north of the watershed near the villages. The 2004 Quickbird image post-dates Park establishment, shortly after animals were removed and 5 years after farming was banned. Thus, meadow loss rates appear to be influenced by a combination of encroachment into abandoned agricultural fields and tree planting associated with national policies. Studies of montane meadow encroachment in the U.S. and European Alps similarly show a rapid successional change from meadows to forest following abandonment of human land-use (Vale 1981; Tasser and Tappeiner 2002; Galop *et al.* 2011).

We cannot conclusively determine whether Park reforestation and afforestation policies are the sole causes of meadow loss in JNP. Factors including climate variability and fire suppression may also contribute to meadow loss. Due to the limited extent of the Quickbird image, we were unable to determine if meadow loss in the Park is accelerated compared to the surrounding landscape. Although other remotely sensed data (i.e., Landsat images) exist, significantly lower spatial resolution on these images prohibits replication of our analysis in areas outside the Park. The Returning Farmland to Forest program has been carried out in neighboring areas as well as within the JNP, but people living outside the Park can still farm and graze their animals. Future research will be conducted to compare the extent of meadow loss in JNP with neighboring areas.

Conclusion

The results of this interdisciplinary study suggest that long-term human land-use, including traditional-scale agriculture and pastoralism, created and maintained montane meadows in JNP. The cessation of human land-use and intentional planting of trees have resulted in substantial loss of meadows with potentially profound implications for the Park's conservation aims. Continued loss of these meadow habitats may result in changes in ecological systems, with lower diversity, fewer ecosystem services, and loss of cultural meaning and traditional knowledge over time.

Our findings from Jiuzhaigou have more general application for conservation practice. The inhabitants of Jiuzhaigou, as in many other areas, have lived as part of the cultural landscape over millennia, and in doing so have significantly shaped the patterns of biodiversity that we see on the landscape. This leads us to rethink conservation that demands removal of human land-use in order to return it to a "natural" state. Our findings are relevant to conservation in protected areas where there is an interest in maintaining existing ecological and cultural structures.

Acknowledgments We are grateful to the residents of Jiuzhaigou who patiently answered our questions and guided us around their environment. Assistance from Professors Tang Ya, Ren Peiyu and Zeng Zongyong, Sichuan University, and Park Superintendent Zhang Xiaoping and Deng Guiping, Jiuzhaigou National Park, are greatly appreciated. We would like to thank Lucy Gelb and Miriam Rothenberg for assistance with map creation. Funding was provided by the by the International Program of the Ministry of Science and Technology of China (2010DFA91280), the "111" Project (B08037), the National Science Foundation's Program in Integrative Graduate Education and Research Training (0333408) and the University of Washington-Sichuan University Exchange Program. Schmidt was funded by a US Fulbright Grant while conducting some research for this project.

Dedicated to the memory of Dr. Debra Friedman, whose vision provided the catalyst for our work.

References

Balmer, O., and Erhardt, A. (2000). Consequences of Succession on Extensively Grazed Grasslands for Central European Butterfly Communities: Rethinking Conservation Practices. Conservation Biology 14: 746–757.

Baur, B., Cremene, C., Groza, G., Rakosy, L., Schileyko, A. A., Baur, A., Stoll, P., and Erhardt, A. (2006). Effects of Abandonment of Subalpine Hay Meadows on Plant and Invertebrate Diversity in Transylvania, Romania. Biological Conservation 132: 261–273.

Bengtsson, J., Angelstam, P., Elmqvist, T., Emanuelsson, U., Folke, C., Ihse, M., Moberg, F., and NystrÃm, M. (2003). Reserves, Resilience and Dynamic Landscapes. Ambio 32: 389–396.

Bennett, M. T. (2008). China's Sloping Land Conversion Program: Institutional Innovation or Business as Usual? Ecological Economics 65: 699–711.

Brandt, J. S., Haynes, M. A., Kuemmerle, T., Waller, D. M., and Radeloff, V. C. (2013). Regime Shift on the Roof of the World: Alpine Meadows Converting to Shrublands in the Southern Himalayas. Biological Conservation 158: 116–127.

Clark, B. (1995). The Quintessence Tantras of Tibetan Medicine. Snow Lion Publications, Ithaca.

Deur, D., and Turner, N. J. (eds.) (2005). "Keeping it Living": Traditions of Plant Use and Cultivation on the Northwest Coast of North America. University of Washington Press, Seattle.

Foster, D., Swanson, F., Aber, J., Burke, I., Brokaw, N., Tilman, D., and Knapp, A. (2003). The Importance of Land-Use Legacies to Ecology and Conservation. BioScience 53: 77–88.

Galop, D., Houet, T., Mazier, F., Leroux, G., and Rius, D. (2011). Grazing Activities and Biodiversity History in the Pyrenees: New Insights on High Altitude Ecosystems in the Framework of a Human–Environment Observatory. PAGES News 19: 53–55.

Gunderson, L. H., and Holling, C. S. (eds.) (2002). Panarchy: Understanding Transformation in Human and Natural Systems. Island Press, Washington, DC.

Halpern, C. B., Haugo, R. D., Antos, J. A., Kaas, S. S., and Kilanowski, A. L. (2012). Grassland Restoration With and Without Fire: Evidence From a Tree-Removal Experiment. Ecological Applications 22: 425–441.

Hellström, K., Huhta, A.-P., Rautio, P., Tuomi, J., Oksanen, J., and Laine, K. (2003). Use of Sheep Grazing in the Restoration of Semi-Natural Meadows in Northern Finland. Applied Vegetation Science 6: 45–52.

Henck, A., Taylor, J., Lu, H., Li, Y., Yang, Q., Grub, B., Breslow, S. J., Robbins, A., Elliott, A., Hinckley, T., Combs, J., Urgenson, L., Widder, S., Hu, X., Ma, Z., Yuan, Y., Jian, D., Liao, X., and Tang, Y. (2010). Anthropogenic Hillslope Terraces and Swidden Agriculture in Jiuzhaigou National Park, Northern Sichuan, China. Quaternary Research 73: 201–207.

Jeanrenaud, S. (2002). Changing People/Nature Representations in International Conservation Discourses. IDS Bulletin 33: 111–122.

Kimmerer, R. W., and Lake, F. K. (2001). The Role of Indigenous Burning in Land Management. Journal of Forestry 99: 36–41.

Kletter, C., and Kriechbaum, M. (2001). Tibetan Medicinal Plants. Medpharm Scientific Publishers, London.

Lett, M. S., and Knapp, A. K. (2005). Consequences of Shrub Expansion in Mesic Grasslands: Resource Alterations and Graminoid Responses. Journal of Vegetation Science 14: 487–496.

Liao, C., Xu, S., and Mo, J. (2009). 九寨沟自然保护区森林资源现状与可持续发展对策 (The State of Forest Resources in Jiuzhaigou Nature Reserve and Strategies for Sustainable Development). Sichuan Forestry Exploration and Design 2: 58–59.

Liu, X. (2007). 生态旅游发展中的生态保护研究:以九寨沟为例 (Research on Ecological Protection in the Midst of Ecotourism: The Example of Jiuzhaigou). Journal of Leshan Teachers' College 22(3): 94–97.

Liu, S., Zhang, X., and Zeng, Z. (eds.) (2007). 九寨沟自然保护区的生物多样性 (Biodiversity of the Jiuzhaigou National Nature Reserve). Sichuan Science and Technology Press, Chengdu.

McShane, T. O., Hirsch, P. D., Trung, T. C., Songorwa, A. N., Kinzig, A., Monteferri, B., Mutekanga, D., Thang, H. V., Dammert, J. L., Pulgar-Vidal, M., Welch-Devine, M., Brosius, J., Coppolillo, P., and O'Connor, S. (2011). Hard Choices: Making Trade-Offs Between Biodiversity Conservation and Human Well-Being. Biological Conservation 144: 966–972.

Miller, J. C., Hammond, P. C., and Ross, D. N. R. (2003). Distribution and Functional Roles of Rare and Uncommon Moths (*Lepidoptera*: *Noctuidae*: *Plusiinae*) Across a Coniferous Forest Landscape. Annals of the Entomological Society of America 96: 847–855.

Miller, T. R., Minteer, B. A., and Malan, L. C. (2011). The New Conservation Debate: The View from Practical Ethics. Biological Conservation 144: 948–957.

Motzkin, G., and Foster, D. R. (2002). Grasslands, Heathlands and Shrublands in New England: Historical Interpretations and Approaches to Conservation. Journal of Biogeography 29: 1569–1590.

Nyima, T., and Tian, M. (2011). Nyima Tashi and Tian Maowang, 1900年至1950年边茶鸦片与松潘城的帮派政治 (Frontier Tea, Opium, and Factional Politics in Songpan City, 1900–1950). Journal of Northwest Nationalities University 1: 51–55.

Pärtel, M., Kalamees, R., Zobel, M., and Rosän, E. (1998). Restoration of Species-Rich Limestone Grassland Communities from Overgrown Land: The Importance of Propagule Availability. Ecological Engineering 10: 275–286.

Peña, D. G. (1999). Cultural Landscapes and Biodiversity: The Ethnoecology of an Upper Río Grande Watershed Commons. In Nazarea, V. (ed.), Ethnoecology: Situated Knowledge/Located Lives. University of Arizona Press, Tuscon, pp. 107–132.

Phillips, A. (1998). The Nature of Cultural Landscapes—A Nature Conservation Perspective. Landscape Research 23: 21–38.

Phillips, A. (2003). Turning Ideas on Their Heads: A New Paradigm for Protected Areas. George Wright Forum 20: 8–32.

Robbins, A. S. T., and Harrell, S. (2014). Paradoxes and Challenges for China's Forests in the Reform Era. China Quarterly forthcoming.

Schmidt, A. H., Montgomery, D. R., Huntington, K. W., and Liang, C. (2011). The Question of Communist Land Degradation: New Evidence from Local Erosion and Basin-Wide Sediment Yield in SW China and SE Tibet. Annals of the Association of American Geographers 101(3): 1–19.

Schulz, C. B., and Crone, E. E. (1998). Burning Prairie to Restore Butterfly Habitat: A Modeling Approach to Management Tradeoffs for the Fender's Blue. Restoration Ecology 6: 244–252.

Stohlgren, T. J., Falkner, M. B., and Schell, L. D. (1995). A Modified-Whittaker Nested Vegetation Sampling Method. Vegetatio 117: 113–121.

Tallis, H., Kareiva, P., Marvier, M., and Chang, A. (2008). An Ecosystem Services Framework to Support both Practical Conservation and

Economic Development. Proceedings of the National Academy of Sciences 105: 9457–9464.

Tasser, E., and Tappeiner, U. (2002). Impact of Land Use Changes on Mountain Vegetation. Applied Vegetation Science 5: 173–184.

Terborgh, J. (2004). Reflections of a Scientist on the World Parks Congress. Conservation Biology 18(3): 619–620.

Trac, C. J., Harrell, S., Hinckley, T. M., and Henck, A. (2007). Reforestation Programs in Southwest China: Reported Success, Observed Failure, and the Reasons Why. Journal of Mountain Science 4(4): 275–292.

Trac, C. J., Schmidt, A. H., Harrell, S., and Hinckley, T. M. (2013). Is the Returning Farmland to Forest Program a Success? Three Case Studies from Sichuan. Environmental Practice 13(3): 350–366.

Urgenson, L., Hagmann, R. K., Harrell, S., Henck, A. C., Hinckley, T. M., Shepler, S. J., Grub, B. L., and Chi, P. M. (2010). Social-Ecological Resilience of a Nuosu Community-Linked Watershed, Southwest Sichuan, China. Ecology and Society 15(4): 2. [online] URL: http://www.ecologyandsociety.org/vol15/iss4/art2/.

Vale, T. R. (1981). Tree Invasion of Montane Meadows in Oregon. American Midland Naturalist 105: 61–69.

Wells, M., Brandon, K., and Hannah, L. J. (1992). People and Parks: Linking Protected Area Management with Local Communities. World Bank, World Wildlife Fund, and U.S. Agency for International Development, Washington D.C.

Wenhua, L. (2004). Degradation and restoration of forest ecosystems in China. Forest Ecology and Management 201: 33–41.

Whitehead, P. J., Bowman, D. M. J. S., Preece, N., Fraser, F., and Cooke, P. (2003). Customary Use of Fire by Indigenous Peoples in Northern Australia: Its Contemporary Role in Savanna Management. International Journal of Wildland Fire 12: 415–425.

Winkler, D. (1998a). Deforestation in Eastern Tibet Human Impact - past and present. In Clarke, G. E. (ed.). Development, Society and Environment in Tibet, Papers presented at the Panel of the 7th Seminar International Association for Tibetan Studies (IATS) Graz 1995. Proc. 7th Seminar IATS, vol.5, Vienna, pp. 79–96.

Winkler, D. (1998b). The Forest of the Eastern Part of the Tibetan Plateau: A Case Study From Jiuzhaigou (Zitsa Degu); NNW Sichuan. Plant Research and Development 47: 184–210.

Wu, G. L., Du, G. Z., Liu, Z. H., and Thirgood, S. (2009). Effect of Fencing and Grazing on a Kobresia-Dominated Meadow in the Qinghai-Tibetan Plateau. Plant and Soil 319: 115–126.

Xu, J., and Melick, D. R. (2007). Rethinking the Effectiveness of Public Protected Areas in Southwestern China. Conservation Biology 21: 318–328.

Xu, J., Yin, R., Li, Z., and Liu, C. (2006). China's Ecological Rehabilitation: Unprecedented Efforts, Dramatic Impacts, and Requisite Policies. Ecological Economics 57: 595–607.

Yuthog Foundation for Tibetan Medicine. Medicinal Plants [WWW document]. URL http://www.yuthog.org/?Tibetan_Medicine/Medicinal Plants (accessed June 28, 2013).

Zhang, P., Shao, G., Zhao, G., Le Master, D. C., Parker, G. R., Dunning, J. B., and Li, Q. (2000). China's Forest Policy for the 21st Century. Science 288(5474): 2135–2136.