Environmental Management (2023) 72:147–159
https://doi.org/10.1007/s00267-021-01514-6

Exploring Indigenous and Local Knowledge and Practices (ILKPs) in Traditional Jhum Cultivation for Localizing Sustainable Development Goals (SDGs): A Case Study from Zunheboto District of Nagaland, India

Rajarshi Dasgupta[1] · Shalini Dhyani[2] · Mrittika Basu[3] · Rakesh Kadaverugu[2] · Shizuka Hashimoto[4] · Pankaj Kumar[1] · Brian Alan Johnson[1] · Yasuo Takahashi[1] · Bijon K. Mitra[1] · Ram Avtar[5] · Priyanka Mitra[6]

Received: 16 March 2021 / Accepted: 23 July 2021 / Published online: 3 August 2021

Abstract

Globally, shifting cultivation is known to be an important driver of tropical deforestation. However, in this paper, we argue that it can be sustainably managed if the environmental boundary conditions, laid by the traditional customs and practices, are fully respected. We narrate an empirical study from the Zunheboto district of Nagaland, India, where we deployed a mixed research method to explore the Indigenous and Local Knowledge and Practices (ILKPs) associated with shifting cultivation (*aka* Jhum), particularly concerning farm-level practices, forest and biodiversity conservation, and disaster risk reduction measures. The research method included analysis of primary data obtained through Focus Group discussions (FGDs), key informant interviews ($n = 21$), and a questionnaire survey ($n = 153$) with Jhum farmers from two different age groups, i.e., below 50 years (middle-aged farmers) and above 50 years (older farmers). From the qualitative inquiry, we identified 15 ILKPs, which were then validated from survey responses. We used the Mann–Whitney U test to examine differences in agreement between two groups of framers. Based on this analysis, we conclude that upholding of the ILKPs holds strong potential for the local implementation of several Sustainable Development Goals (SDGs), particularly, SDG-1 (No poverty), SDG-2 (Zero hunger), and SDG-15 (Life on land). However, eight of the identified ILKPs showed a statistically significant difference between older and middle-aged farmers, underlining a declining trend. Finally, we suggest suitable policy measures to mainstream ILKPs to balance the trade-offs in food production and biodiversity conservation, and to ensure the future sustainability of Jhum cultivation in the region and beyond.

Keywords Agricultural Heritage · Landscape sustainability · Conservation · Disaster Risk Reduction (DRR) · Food security

Introduction

Home to thousands of indigenous communities, mountains of South and Southeast Asia are rich repositories of traditions and culture. Slash-and-burn cultivation, also known as shifting cultivation, is the traditional farming method that is practised in these mountains since time immemorial (Cochrane 2003; Kumar et al. 2016; Mohapatra et al. 2017; Thomaz 2017). Typically, shifting cultivation involves clearing and burning of forests on mountain slopes up to

✉ Rajarshi Dasgupta
dasgupta@iges.or.jp

[1] Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan

[2] CSIR National Environmental Engineering Research Institute (NEERI), Nagpur, India

[3] Graduate School of Global Environmental Studies and Graduate School of Agriculture, Kyoto University, Kyoto, Japan

[4] Graduate School of Agriculture and Life Sciences, The University of Tokyo, Tokyo, Japan

[5] Faculty of Environmental Earth Science, Hokkaido University, Hokkaido, Japan

[6] Graduate School of Media and Governance, Keio University, Fujisawa, Japan

1500 meters, cultivation for a year or two, and then leaving the land abandoned for forests to regrow and engulf the abandoned land. A typical cycle of 10–15 years is maintained in this process, which ensures the complete regrowth of the forests. In other words, shifting cultivation practices are rotational, where mountains adjacent to each other are cultivated for sustenance.

It is estimated that more than 250 million people living in the tropical regions practice shifting cultivation and that land under shifting cultivation accounts for ~30% of all cultivated land in the world (Altieri 2004; Metzger 2003). Slash-and-burn cultivation is extensively practised by the local indigenous communities in the eastern Himalayan region, including most of the Northeastern hilly states of India, where it is locally known as *Jhum* (Aayog 2018; Kumar et al. 2016). More than 100 Indigenous Peoples and Local Communities (IPLC) of northeast India, including over 620,000 households, depend on Jhum cultivation. As of 2018, the total Jhum cultivated area spans over 8500 sq. km. (Aayog 2018). This accounts for more than 85% of the cultivated lands in Northeast India (Kumar et al. 2016).

Jhum farming plays a profound role in the regional food security, wealth distribution, peace, harmony, and wellbeing of the indigenous tribal communities. All these contribute to the economic and social development of the region, thereby, facilitating the local implementation of multiple Sustainable Development Goals (SDGs). Apart from its direct contribution to food security and livelihood in the isolated mountainous regions, Jhum is also known to be a ritually sanctioned way of life, a measure of self-identity that is deeply rooted in the ethos, culture, and magico-religious pursuit of the tribal mountain communities (Gupta 2005).

Environmental Adversaries of Shifting Cultivation

Despite the contribution of shifting cultivation in local food security, it is often reported that the slashing of the forest for short-term agricultural gains is unequivocally unsustainable. Shifting cultivation and the clearing of forests bear large-scale pronounced impacts on environmental systems like regional hydrology, carbon stock, forest fires and the delivery of other ecological benefits (Aayog 2018; Kumar et al. 2016; Metzger 2003). It has been declared among the primary agents of deforestation responsible for nearly 70 percent of the tropical deforestation in Africa, 50 percent in Asia, and 30 percent in Latin America (Sanchez et al. 2005). Increasing population and human consumption further exacerbated the adverse effects of frequent slash-and-burn cultivation and reduction of cultivation cycles (Kumar et al. 2016; Mohapatra et al. 2017; Thong et al. 2018).

As such, studies related to slash-and-burn agricultural practices can be classified into two different groups, namely, (a) forest floor-level micro studies (e.g., on nutrients availability, microbial biomass, organic matter, soil fertility, soil aggregate stability, etc.) and (b) landscape-level forest management (on conservation, regeneration, land-use changes, deforestation, biomass, etc.). Although there are some observed short-term benefits in soil fertility after slashing and burning the forest biomass (Wick et al. 2005), the subsequent leaching of nutrients and organic carbon causes more harm than benefit (Ritse et al. 2020). Some researchers, for instance, compared the short and long-term dynamics of the soil organic carbon (SOC) stocks between Jhum cultivated cropland and undisturbed forest stands and observed that in the short-term (1–5 years), the decline in SOC under Jhum is predominant, and the losses become steady in the range of 5–10 years (Mishra et al. 2019). Nevertheless, the local factors such as terrain, precipitation pattern, soil texture, etc. significantly influence the soil nutrients after the slash-and-burn practices. Further, the fallow period between the crops also influences soil fertility (Metzger 2003). The amount of soil carbon and nitrogen is found to be greater in the long fallow period (10 years) when compared with the short fallow period (2 years) (Hauchhum and Tripathi 2019). Most farmers follow a practice of 10 years fallow period in this region, but some researchers mentioned that a period of 12–25 years would be ideal for improving soil fertility (Teegalapalli et al. 2018). In short, soil erosion and degradation have been widely reported after shifting cultivation. Especially, owing to the lack of litterfall on the forest floor, the soil becomes harder and modifies the entire surrounding landscape. Thus, Jhum cultivation is held responsible not only for the direct deforestation but also for the degradation of adjacent healthy primary forests (Metzger 2003).

There are, however, few studies that have integrated the dynamic environmental feedback on the forest and agricultural systems due to the modification of land use that occurred by slash-and-burn practice. For instance, Gay-des-Combes et al. (2017) have related the intensity of extreme precipitation that had resulted from the decline in forest cover due to the slash-and-burn cultivation. Moreover, the excessive precipitation has resulted in an aggravated loss of soil nutrients. Nevertheless, the cycle of forest degradation needs to be understood at the systems level with proper integration with sociocultural ramifications, especially in the light of climate change and local food security.

Indigenous and Local Knowledge and Practices (ILKPs) for Landscape Sustainability

Globally, indigenous and traditional agriculture practices have already proven their efficiency, adaptability, and resilience for sustainable food production (Thong et al. 2018). Likewise, Jhum cultivation following indigenous

and traditional ecological knowledge (ITEK) provides a long-evolved sustenance model of mountain agriculture and food production in isolated hilly regions (Upadhaya et al. 2020). Although diverse views thrive on the environmental and economic aspects of extensive deforestation for Jhum cultivation, the very fact that the method survived thousands of years marks its ultimate credential.

Some researchers deliberate Jhum cultivations as a diversified climate-resilient practice that is suitable to heavy rainfall in mountain areas, but many portrayed Jhum as primitive and incompetent practice (Goswami et al. 2012; Mohapatra et al. 2017; Rasul and Thapa 2003). There is no denial of the fact that plenty of evidence is available which exemplify the adverse ecological consequences of Jhum cultivation. For instance, a recent study reported more than 114.46 km^2 area is annually slashed for current shifting cultivation in Mizoram, while the cultivated areas account for less than half of it (Thong et al. 2018). Another study found that 80.61% of the Jhum cultivators (*hereinafter* Jhumiyas) observed a significant reduction in forest area over the last few decades (Paul et al. 2017). However, this may be primarily due to the loss of traditional knowledge and practices, which laid strict environmental boundary conditions, and safe operating place of Jhum cultivation in the fragile mountain terrain.

Historically, the IPLCs inhabiting the region are recognized for their shared and healthy interactions with their surrounding natural environment. Jhum is an integrated method and an agricultural heritage to create agro-ecosystem in the most challenging topographies that involves natural forests, biodiversity, soil, and livestock management following Indigenous Traditional Ecological Knowledge (ITEK) systems, in association with institutions and customs that have co-evolved over the years (Bhagawati et al. 2015). ITEK systems of preserving soil fertility, pest management, averting soil erosion, protecting the grains and seeds, selection of seeds, and managing the environment have a fundamental role in supporting the shifting cultivation and their natural environment (Senotsu and Kinny 2016). Besides, replacing Jhum with permanent agriculture may bring even worse consequences for mountain ecology.

Jhum cultivation practised today, nonetheless, is a gross departure from its past in many respects. Particularly, much of the indigenous knowledge and traditional landscape management practices, which laid the strict environmental boundary conditions, have been disappearing as the local communities' embraced modernism. The uses of Indigenous Local Knowledge (ILK) and traditional landscape management practices continue to decline with the widespread conversion of livelihood and traditional lifestyle, increase in population, democratization, and loss of the authority of the traditional local institutions. Therefore, it is imperative to identify and integrate the traditional landscape management practices and ILKs into the present form of Jhum cultivation, which can make a critical difference in landscape sustainability and facilitate the conservation of forests and biodiversity.

Under this backdrop, this paper narrates an in-depth survey of *Jhumiyas* in Nagaland to identify the ILKPs related to Jhum cultivation and landscape sustainability, including the customary rules, practices, values, and ceremonial uses. Among the Northeastern hilly states of India, Nagaland enjoys a great deal of autonomy, which is often criticized for the rapid propagation of Jhum farms and reckless deforestation. This present work outlines an exploratory study to document the ILKPs in Jhum cultivation from Nagaland, and possibly among the first study to report how such perceptions vary across age groups. We further discuss how the formal adoption of ILKPs can facilitate localizing the SDGs, particularly balancing the trade-offs in food production and biodiversity conservation, and support a sustainable regional development model.

Material and Methods

Study Area

The present study was conducted in Zunheboto, one of the eleven mountain districts of Nagaland (see Fig. 1). The district is home to Sümi Nagas, who among the sixteen major Naga ethnic tribes of the state. The name "Zunheboto" is derived from two different words, namely, *"Zunhebo"*, a local flower, and "*To*", meaning the hilltop in the local dialect. Thus, the name Zunheboto translates as the flowers on the hilltop. Once headhunters and later baptized by Christian missionaries during the second world war, the Sümi Naga tribe is known for their system of hereditary chiefdom, beautiful rhythmic dances, and the philosophy of living of the land (Census of India 2011).

Zunheboto is located remotely at about 225 km from Dimapur, the nearest entry point with an airport and railway station that connect Nagaland to the rest of the country. Centered across the small township of Zunheboto, the district spreads across several mountain hamlets and encompasses an area of 1255 sq. km. Geographically it is bounded between 25° 27′ and 26° 18′ northern latitudes and 94° 15′ and 94° 40′ Eastern longitudes and located at an average elevation of 1852 m above the mean sea level. The district is located amidst moist mixed deciduous forests and subtropical pine forests. The dominant floral species are oak, chestnut, birch, burflower and secondary bamboo trees. The area is also well known for high avian diversity, including over 200 species of birds. Some of the locally significant avian species include the Great Barbet (*Psilopogon virens*) Blyth's Tragopan (*Tragopan blythii*) and the Indian Cuckoo (*Cuculus micropterus)* Sema language). Other important

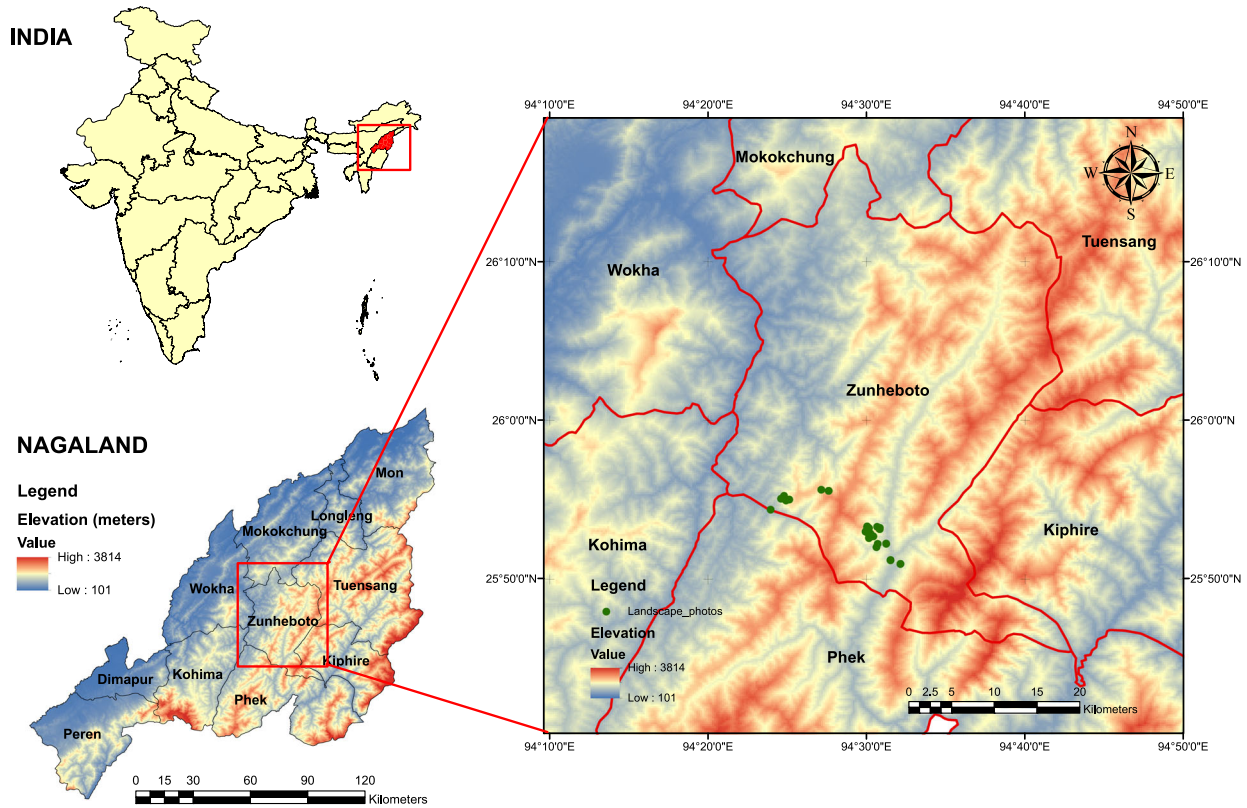

Fig. 1 Location map of the study area. The green dots represents the locations of landscape photographs ($n = 417$). Elevation is reported in meters above the mean sea level

faunal species are the Sambar (*Cervus unicolor)*, barking deer (*Muntiacus muntjak*), red serow (*Capricornis rubidus*), Fishing Cat (*Prionailurus viverrinus*), and Chinese Pangolin (*Manis pentadactyla*) (Edake et al. 2019; Mishra and Francaviglia 2021).

Nearly, 85% of the population are rural and typically depend on Jhum cultivation for daily sustenance (Rawat 2014). According to the latest census report (2011)[1], the district has a population of 140,757, with a population density of 112/sq. km. Agriculture, by far, serves as the primary livelihood of the district and the backbone of the rural economy. The major harvested product through Jhum includes rice (*Oryza sativa*), maize (*Zea mays L.*) and mixed vegetables, including potato (*Solanum tuberosum*), ginger (*Zingiber officinale*), and other seasonal vegetables (Mishra and Francaviglia 2021).

Data Collection and Analysis

To identify the ILKPs related to Jhum cultivation, forest conservation, and disaster risk reduction (DRR), we used a mixed research method that included both qualitative and quantitative data collection and analysis. Participatory Rural Appraisal (PRA) tools including Focus Group Discussion (FGD) and Key informant surveys were used initially, followed by a short questionnaire survey of Jhum farmers in selected villages in the district ($n = 153$). In addition, we captured over 400 geo-tagged landscape photographs representing different stages of Jhum cultivation and surrounding landscapes as visual references, which were later used for photo-analytical purposes (see Fig. 1). Visual methods, such as the photo-analytical approaches are among the traditional methods to capture and verify meaningful information on landscape practices. Here, the landscape photographs were used as primary evidence to support the narratives of the local communities.

The study was conducted in two phases. At first, we conducted three exploratory FGDs and Key informant Interviews ($n = 21$), between 3rd to 8th June 2019. Table 1 outlines the important points that were asked, along with the open-ended questions, which were used for Key informant interviews. These questions were asked to guide and steer the discussion, to get the best possible information on the Jhum cultivation cycle, the use of ILKPs in the entire process and the challenges and opportunities in future sustainability. The PRA exercises were carried out in Sukhai and surrounding villages and landscape photographs were collected from the same locality (see Fig. 1). In total, three

[1] According to the last census conducted in 2011. The next census report is due in 2021.

Table 1 Guiding questions for the focus group discussions (FGDs) and key informant surveys to identify ILKPs

- Please explain the Jhum cycle, including its different stages, such as slashing, sowing, and harvesting?
- What kind of cropping practices and preventive measures you take before, during, and after Jhum farmers, particularly related to soil conservation, control of water pollution etc.?
- Do you think the current Jhum practices are sustainable, if not, please explain the specific reasons?
- Can you explain any rituals, landscape practices that you believe to be effective for the sustainability of Jhum cultivation?
- What kind of measures do you take for biodiversity conservation and the protection of natural forests?
- Please explain the observed environmental impacts

FGD discussions were carried out with Jhum farmers (15 participants), women self-help group (12 participants), and community representatives and local government officials (8 participants) respectively.

This was followed by key informant interviews of 21 villagers, including both men and women from diverse occupational background (e.g., farmers, hunters, workers, government employees, etc.). The first author, in association with other volunteers, conducted these interviews. During the interviews, we asked the respondents about their socioeconomic background and sought information on: (a) the complete practice of the Jhum cultivation, starting from the clearing of the forests to harvest, (b) major landscape, conservation, and social practices and (c) sociocultural ties with the landscapes, including festival, customary and ceremonial values and (d) Likely avenues to enhance the socioeconomic and environmental sustainability within the current Jhum farming arrangement.

During the entire course of the interview, the first author and key interviewers listened to the narratives carefully and encouraged discussion through probing questions. Based on the directed content analysis and frequency mapping, we listed 15 traditional landscape, forest management, and DRR practices, which were later verified through a confirmatory questionnaire survey. The questionnaire survey included a five-point Likert scale against each of the shortlisted ILKPs and was conducted by experienced survey teams in the latter half of 2020. In each of the steps, empirical data were collected in close association with an experienced local interpreter, who supported meticulous and on-the-spot translation in the local language.

For qualitative data, all the proceedings were audio recorded. These audio transcripts were later transformed into thematic reports containing specific issues, statements, and observations. This is among the standard data reduction technique, which is capable of summarizing a large amount of unprocessed data (DasGupta and Shaw 2017). The summary reports were further subjected to directed content analysis to identify specific practices related to: (a) farm-level landscape sustainability, (b) forest conservation practices, and (c) indigenous practices related to DRR (see Table 2 for details of the ILKPs).

Auxiliary information from government reports, contemporary scientific papers were also taken to strengthen the evidence derived from the above-mentioned analysis. For analyzing the data from the questionnaire survey, we performed the Mann–Whitney *U* Test to compare the difference in agreement among older and middle-aged farmers, i.e., aged more than 50 years ($n = 88$) and middle-aged farmers, i.e., aged below 50 years ($n = 65$). The tests were performed using SPSS™ (V 27).

Results and Discussion

In Nagaland, Jhum cultivation functions following Ostrom's principles on Common-Pool Resources (CPR) under the supervision of customary local institutions. Elinor Ostrom's legendary work on Common-Pool Resource (CPR) management defined eight core principles for exploring and managing the social dynamics surrounding shared resources. These include: (1) clearly defined boundaries, (2) congruence, (3) collective decision-making ability, (4) Monitoring member's behavior, (5) Graduated sanctions for violators, (6) Conflict-resolution mechanisms, (7) Recognition of rights, and lastly (8) Nested enterprises (Ostrom 2002; Ostrom et al. 1999). As such, all the major steps in Jhum cultivation, starting from the site selection, clearing of forests to the harvest of food grains are governed by a set of customary rules, which are nested around these eight principles. While a plethora of ILKPs is followed at every stage, which is unique to each tribe, we facilitate the results from the PRA exercises under the four interlinked research dimensions, namely, (1) The traditional Jhum calendar, including land selection, DRR, and farm-level ILKPs, (2) ILKPs related to landscape sustainability and ecological conservation, (3) Differences in perceptions of ILKPs between middle-aged and old farmers, and (4) Key sustainability issues in Jhum cultivation and ways to improve it, including localizing the SDGs.

The Traditional Jhum Calendar and Farm-Level Knowledge and Practices

The preparation of Jhum cultivation begins with the site selection, which is typically followed by slashing, burning, sowing, weeding, crop protection, and harvesting at different intervals. The Jhum calendar is summarized in Fig. 2. Each tribe, under their leaders and/or institutions, has some location-specific and unique calendar for Jhum cultivation. In the case of the Sumi Naga tribe, Jhum cultivation begins in early September, soon after the village chief decides the plot

Table 2 Indigenous local knowledge and practices (ILKPs) in traditional Jhum cultivation

	Code	MD Middle-aged farmers	MD Old farmers	*U*	*r*
Communities develop mixed crop for Jhum cultivation for better resilience (Jhum paddy, Soybean, etc.)	[FLP]	4	4	2688.0	0.06
Mixed cropping increases soil fertility which is generally suitable for mountain landscapes	[FLK]	4	4	1960.0	0.38[a]
The traditional songs/customs used for Jhum strongly symbolizes the Naga culture and unity.	[FLP]	4	4	2816.0	0.09
Deforestation/Slashing for Jhum is restricted in steep/higher slopes	[DRRP]	4	4	1696.5	0.10
Deforestation for Jhum is restricted close to rivers to prevent deterioration of river water quality	[DRRP]	4	4	1823.0	0.39[a]
The rotational cycle of Jhum (about 10 years) is ideal for forest regrowth.	[FM]	4	4	2102.0	0.29[a]
The method Jhum is better than permeant agriculture which leads to more soil erosion	[FLP]	4	4	1844.0	0.37[a]
The decision for Jhum land selection is based on traditional site suitability analysis by the village head	[FLP]	5	4	2717.5	0.04
There are no commercial markets out of Jhum cultivation, all is for domestic/ village consumption	[FLP]	2	3	2100.0	0.24[b]
Regrown forests after Jhum are generally more diverse than the native forests.	[FM]	4	4	2816.0	0.09
The use of pesticides is generally restricted in Jhum cultivation.	[FLP]	4	4	2036.0	0.38[a]
Border cropping, including agroforestry is practiced to reduce soil erosion and protection from wild animal attack.	[FLP]	4	4	2650.0	0.07
It is customarily prohibited to hunt pregnant animals.	[FM]	4	4	2795.0	0.07
The consumption of Jhum products (food) are shared among villagers.	[FLP]	3	4	2057.0	0.27[b]
Meat from the hunted animal is customarily shared with the villagers.	[FM]	4	5	1895.0	0.33[a]

FLP Farm Level Practice, *FLK* Farm Level knowledge, *DRRP* Disaster Risk Reduction practices, *FM* Forest Management, *MD* median, *U* Mann–Whitney's U-statistic, *r* effect size estimate ($r = Z/\sqrt{n}$; n = number of observations)

[a]Difference is significant at the 0.01 level (two-tailed)

[b]Difference is significant at the 0.05 level (two-tailed)

for slashing. This is typical of the Sumi tribe, who are known for their traditional chiefdom. However, for many other tribes, the decision is taken by the village institutions or through rigorous participatory processes. Interestingly, each of the Naga tribes has its system of governance, ranging from full authoritative governance to complete democracy (Chasie 2001). During the FGDs, the local communities reported that the decision is taken in a customary meeting, locally known as *Saghuni*. This meeting is generally called for the preparation of harvest, where the village chief also announces the plot for next year's cultivation.

Some core principles are followed while selecting a potential site. For instance, steep slopes are generally avoided since it enhances the risks of landslides (and soil erosion) and is difficult for the regrowth of forests. Secondly, Jhum is always conducted at the lower slope, i.e., on the downhill side of the village. This is to reduce the chances of landslide damage to the settlements, also to protect the forests on the steeper slopes. Besides, some farmers also reported that areas that are close to the riverside are not cultivated, considering the possibility of deterioration of river water quality. Moreover, it is customary not to cultivate the land located within the immediate vicinity of the villages. The Jhum fields are located far away from the settlements, a measure probably adopted historically to maintain a clean and green environment in the surroundings and a natural defense from enemy tribes. The Jhumiyas generally walk together in the morning through the steep mountain slopes. For instance, one farmer said:

> "Jhum is not just an agriculture practice; it is the way we live and adapt to this difficult terrain. We walk miles together in the morning to the Jhum fields…. (in doing so) we remain physically fit and develop a strong bonding with each other… we share food and help each other in the time of need".
>
> -response from a Sümi Naga farmer, male (64)

The forest is cleared over the next 3 months, i.e., October, November, and December. The onset of winter helps

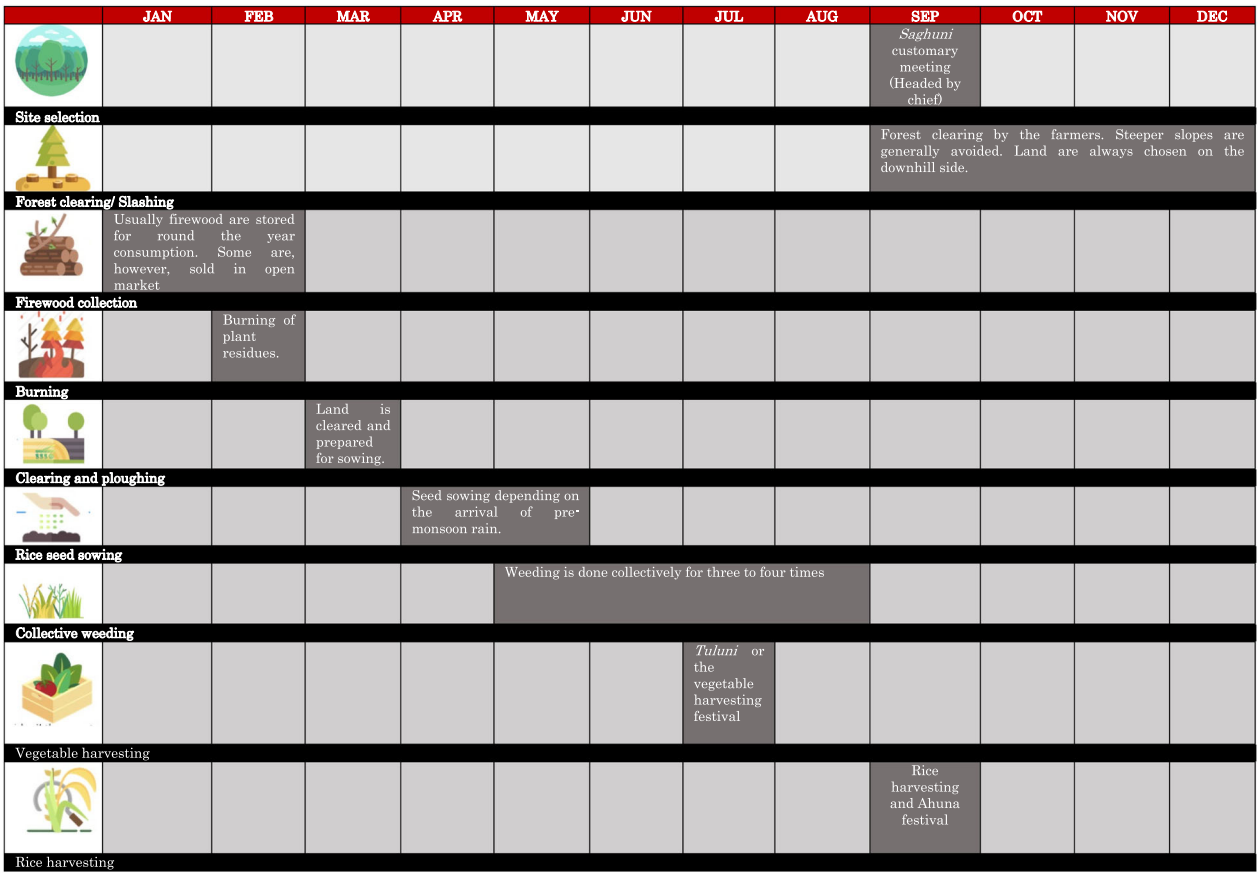

Fig. 2 Jhum calendar as revealed by the local communities

quick drying of trees and branches. At the beginning of January, Jhumiyas collect the dried trees and branches and store them as fuelwood for the whole year. However, Some Jhumiyas also sell these in the local markets. The remaining residues, including the cleared shrubs and undergrowth, are burned in February and the entire field is cleared and ploughed by March (see Fig. 3a). The ash from the dried leaves, small branches make the land particularly fertile and supply the essential nutrients.

The village chief assigns similar plots to all Jhumiyas to cultivate independently. March is the main sowing season and the Jhumiyas purposefully develop mixed crops consisting of Jhum paddy, maize, pulses, pumpkins, ginger, and varieties of other vegetables to manage the risk of crop failure. The paddy seeds are sown in early April, depending on the onset of pre-monsoon rain. This is harvested in early September. Generally, paddy is cultivated on terraced land and vegetable and maize are cultivated on slopes (see Fig. 3b, d). Besides, boundary agroforestry or mechanical barriers by stone/log are often developed to protect the crops from wild animals as well as to restrict soil erosion.

In July, the first vegetable harvest season begins, which is followed by an important harvest festival called "*Tuluni*", which means "*the season of bountiful yields*". Traditional prayer is offered for the success of sown crops to the Litsaba, the God of productivity and crop protection. This festival is usually celebrated on the 8th day of July, however, in recent years such practices declined. Over the next few months, collective weeding is done three to four times before the paddy is harvested in early September. *Ahuna* is the popular traditional post-harvest festival and is generally celebrated on the 14th of September. On this Thanksgiving Day, the tribe cooks their first meal with harvested rice, typically cooked in small bamboo segments and shared across the community. The harvest is primarily for family consumption and seldom sold over commercial markets. Interestingly, each of the Jhum steps, from slashing, sowing, weeding to harvesting are associated with traditional theme songs, which are unique to each tribe and are primarily dedicated to nature.

ILKPs in Landscape Sustainability and Ecological Conservation

Jhum cultivation is primarily detrimental to the loss of forest cover and causes uncontrolled soil erosion. The current

Fig. 3 Selected photographs of different indigenous and local practices in Jhum cultivation (**a**) burning of residues after clearing and drying the forests, (**b**) traditional earthen/stone boundary walls are created on benches to prevent soil erosion, and (**c**) Jhum farming are generally conducted at lower /favorable slopes and steeper slopes are generally avoided. Also, it is cultivated away from the villages (**d**) steeper slopes are generally selected for less water intensive crops, such as maize, whereas rice is grown on relatively flat terrains (**e**) home garden is a popular adaptation option for supplementing food production, and (**f**) no Jhum land is located in the riverside for reducing disaster and environmental risk. In the picture is the Teez river. Note: The pictures are some of the prevailing best examples of ILKPs related to landscape practices, however, the customary rules often vary from one village to another

challenges for the communities in managing the landscape sustainability mainly consist of decreasing Jhum cycles, which is a direct consequence of population growth and commercialization of Jhum products. Some villagers reported that Jhum was conducted originally for domestic consumptions only, which later were commercialized. Nonetheless, historically, when a particular piece of land is cultivated for one or two consecutive years, the same plot is left abandoned for about 30 years for the forests to regrow. However, the current cycle has reduced to less than 5 years, which does not allow the proper regeneration of the forests. When asked, the local community mentioned that the gap of 10 years is generally appropriate for the growth of native vegetation. They further informed that naturally, regrowth forests are often more diverse as compared to the older forests.

During the FGDs, the old respondents reported that traditionally, the chief of the clan did not allow cultivating the plots that had young and immature forests, and a gap of at least 10 years was enforced to allow the satisfactory regrowth of the forest. In the series of interviews, it was revealed that the main problem lies in the high number of farmers due to population growth combined with agricultural commercialization, which now requires larger land to be deforested and cultivated. All the tribes in Nagaland maintain a distinct clan boundary and therefore, to provide adequate farmland to the Jhumiyas, there is direct pressure on the forest, alongside its consequence of landscape sustainability.

The forested landscapes of Nagaland are also incredibly diverse in terms of biodiversity, spanning over two globally important biodiversity hotspots, the eastern Himalaya and the Indo-Myanmar region. Unlike the other Indian provinces, the majority of natural habitats in Nagaland are not owned by the Government, but by clans and traditional institutions. Therefore, Indian wildlife and forest conservation laws are not applicable (Subramanian et al. 2013). The Article 371A of the Indian constitution mandates the special recognition of the customary rights of the Naga tribes, including the ownership and transfer right of land and its resources. Therefore, in the absence of any preventive legislation, indiscriminate fishing and hunting are rampant almost all across Nagaland.

Hunting and bushmeat consumption are customary to all the Naga societies. Bushmeat consumption is sometimes preferred over domestic meat and has ceremonial uses. However, with the indiscriminate use of destructive fishing gear (e.g., electric fishing, poison, etc.), the population of wild animals reduced alarmingly in recent years. During the FGDs, the local communities mentioned that in their childhood, the village elders prohibited the overexploitation of wildlife, particularly mammals, and enforced various customary rules. The elders reported that traditionally it was prohibited to hunt pregnant mammals, particularly during March to May. These 3 months were considered the major mating and spawning season according to the traditional calendar. For instance, one elderly person said:

> "From the time immemorial, the elders and village chief prohibited us to hunt or fish from March to May. We are not biologists, but our elders knew a lot about animal behavior…during this time mammals get pregnant...it is customary not to hunt animals during this time. Hunting was only allowed from September to December."
>
> -Village elite, Sümi naga aged about 72 (male)

The surrounding forests and large trees, in particular, were historically considered as the dwelling place of spirits and deities (Senotsu and Kinny 2016). The Naga communities have customary rituals to beg for forgiveness during the Jhum cultivation as clearing of forests often damage smaller animals and reptiles. As such, the Naga culture epitomizes a fear and respectful attachment to the forests, which are believed to be protected by spirits. The local indigenous communities still believe in lycanthropy-souls of people entering bodies of tigers, snakes, etc. Sumi nagas, in particular, share an intricate relationship with the tiger. There are numerous stories and folklore about tigers in the Naga Community. The tigers are considered as the ancestral brother of man, along with the spirit. For instance, one elderly people said:

> "If one killed a tiger by chance, the hunter had to put water in the tiger's mouth so that it would not utter his name. Otherwise, the hunter will be cursed for a lifetime. Likewise, in our tradition, we never kill the yellow marten. It is a symbol of adversity. If you see this, the day becomes ill-fated… Hunters return immediately if they encounter a yellow marten"
>
> -Ex-hunter Sümi Naga tribe, aged 66 (male)

Differences in Perceptions of ILKPs

After performing a directed content analysis on the qualitative inquiry, we listed 15 ILKPs, including farm-level knowledge and practices, DRR related practices, and knowledge/practices related to forest conversation and management. Table 2 summarizes the identified ILKPs along with their category. Overall, we collected 153 responses, consisting of two groups of farmers, namely older and middle-aged farmers. The average age of the farmers was 52.8 years, which is representative of the ongoing outward migration of young working adults. The average age of the <50 years group was 43.4; while the average age of the above 50-year group was 59.2. Of the 153 farmers, 131 farmers, or 85% of the respondents, were male. Almost the entire population of farmers is economically vulnerable and the monthly average income is just 3067 rupees (~42 USD), which is less than half of the national average income of farmers.

To examine differences in the agreement on the observed ILKPs between two groups of farmers, we performed the Mann–Whitney *U* Test. Out of the fifteen listed ILKPs; eight showed a statistically significant difference in perception (see Table 2). As such, the results showed a subtle declining trend of appreciation of ILKPs among middle-aged farmers. For example, it was observed that the philosophy of sharing Jhum products or meat from the hunted animals is not very prominent in middle-aged farmers as compared to older farmers. Similarly, it was apparent that the traditional method of cultivating crops without pesticides is little respected among the younger generation. Differences were also observed in sustainable landscape practices such as not diverting the forest on the riverside and the years for the Jhum cycle, which shows that the appreciation for traditional knowledge and practices are somewhat fading among the younger farmers.

Role of ILKPs in Localizing Sustainable Development Goals

Much like the rest of the world, Jhum cultivation in Nagaland is structurally complex, with multiple conflicting social, cultural, economic, and ecological interests. While farm-based livelihoods are central to rural development and human wellbeing in Nagaland, the current form of Jhum cultivation, due to its destructive methods and practices has received widespread criticism from conservationists. More so, population explosion has further invariably affected the ecosystem resilience and landscape sustainability in the region. Many feared that there is a strong potential of a decrease in Jhum produces over the next decade, raising issues of livelihood security and resilience among people

who are currently depending on shifting cultivation (Heinimann et al. 2017). Apart from its immense cultural and place significance, there are many ways Jhum is linked with the social and economic development of the local communities. Moreover, the communities reported massive inward migration following the COVID outbreak, which put additional pressure on an already exhausted forest and natural resources.

Niti Ayog[2], India's highest developmental planning body, found the relevance of Jhum cultivation in realizing SDG goals and its targets, namely SDG-1 [End poverty] (1.4, 1.5); SDG-2 [zero hunger] (2.1, 2.2, 2.3, 2.4, and 2.5); SDG 6 [water and sanitation] (6.1, 6.4, 6.6), SDG 13 [climate action](13.1) and SDG-15 sustainable use of ecosystems i.e., [life on land] (15.1, 15.2, 15.3, 15.4, and 15.5) (Aayog 2018). Jhum has been the traditional way to ascertain food security and livelihood in remote mountain regions with little diversification over the years. It has contributed to localizing the SDGs, particularly SDG-1 [End poverty] and SDG-2 [zero hunger], but critics argue that it also grossly undermined the other environment and conservation goals such as the SDG-15 [Life on the Land]. Therefore, with little space for innovation and diversification, undermining the IKLPs can bring catastrophic consequences on food security [SDG-2 (Zero Hunger)] and livelihood security [SDG-1(End poverty)] in the region.

Prevailing ILK systems encourage having better yields with the least environmental damage, which includes avoiding water-rich and steep slopes for cultivation plots or provide adequate time for forest regrowth. Taboos and traditional restrictions further contribute to safeguarding some important species, particularly birds. For instance, the Hornbill Festival, the largest festival celebrated across all the major tribes of Nagaland, is named after the Great Hornbill *(Buceros bicornis*). Locally, this bird is considered a symbol of beauty, grandeur and alertness and evokes much respect from the local communities. It was, nonetheless, evident from the PRA exercises that the loss of power and respect in the traditional village institutions had some negative consequences on the ITEK, which increased the trade-offs between socioeconomic and conservation goals. The complexity of prevailing legal systems, including the customary roles of local institutions and communities in resource governance, further escalated this problem. The local tribal communities, while ruling out the likeliness of permanent agriculture in the region, proposed several likely adaptation measures, which in combination with the ILKPs should foster some degree of resilience in the current form of Jhum cultivation. While trade-off between environment and social development goals are often inevitable (DasGupta et al. 2019), ILKPs can act as a potential tool for optimization, once mainstreamed into policy actions.

There is also a growing need to promote livelihood and income diversification in the region for marginalized farmers through strengthening agriculture extension programs. Supporting livelihood diversification schemes through the promotion of enterprises like dairy, poultry, and pig farming has been recently facilitated through some government and nongovernment programs. Besides, several rural ecotourism hubs have been created to attract tourists. In this regard, designation of Globally Important Agricultural Heritage Systems in the fascinating mountain landscapes may ensure a consistent supply for tourists. Likewise, home gardens, the development of food forests, and community conservation areas also hold strong potential for localizing poverty reduction goals. ILKPs such as the practice of border cropping have great potential to halt soil erosion while maximizing benefits through harvesting of Non-timber Forest Products (NTFPs). However, to promote all these across the sixteen Naga tribes, a detailed need assessment should be conducted. Further research is also needed to understand the diverse employment opportunity in the traditional handicraft sector.

Policy Recommendation

Jhum cultivation supports nearly 60% of the livelihood in Nagaland and over 60% of food demand in the state. As it is often said in Nagaland, *"No Jhum means no food"*. Given such a situation, the success of Jhum is intertwined with the local community's social, economic, and cultural development. At the same time, it is impossible for locals to significantly and instantaneously change their traditional livelihood. Any policy that targets sustainable and transformative changes in the existing Jhum cultivation system, should therefore be drafted within the scope of prevailing sociocultural philosophies of the Naga communities (Paul et al. 2020). In other words, to promote structural and environmental resilience in Jhum cultivation, policy planners should take softer adaptation approaches, and interventions should be based on the combination of existing ITEK and modern scientific knowledge. Dhyani et al. 2020 argued that the indigenous and traditional knowledge-based production system with some modification that applies scientific inputs can help withstand the indigenous Jhum practice. Other researchers also mentioned that the ITEK, culture and local beliefs of IPLC need to be harnessed and should supplement the modern science for improved and sustainable use of natural resources with the context of shifting cultivation (Bhagawati et al. 2015; Priyadarshini and Abhilash 2019).

[2] Niti Ayog, formerly known as Planning Commission of India is the highest planning body of India

Considering these, we propose a three-tiered sustainability framework consisting of: (a) supporting livelihood diversification, (b) Enhance farm-level resilience through the integration of ITEK and modern agriculture practices, and (c) enhancing community awareness and conservation measures. Strengthening local governance of village councils by involving stakeholders that are more relevant is necessary to implement such a framework. In the following paragraph, we briefly illustrate the suggested measures.

Jhum is the only livelihood of the state, catering to the majority of the Naga communities. However, it is not always economically rewarding. The competition over farmland is one of the leading causes for the traditional Jhum cycle to decline beyond the conventional 10 years' limit. This contributed to enormous pressure on the adjacent forests, in both Zunheboto and all other districts. Enhancing livelihood opportunities through ecotourism, animal husbandry, forest product processing, handlooms, etc. are extremely critical to sustain alternative livelihood and divert people from Jhum farming. In this regard, the state government of Tripura achieved some success by providing various non-farming opportunities to Jhumiyas. However, there is still a need to create more such opportunities to implement short and long-term control measures in Jhum cultivation (Gupta 2000).

At the farm level, value addition through the rigorous adoption of ITEK and modern scientific knowledge holds strong potential. For example, introducing a formal organic certification scheme for not using pesticides can enhance the market values of Jhum products. As we observed in this study, Jhum cultivation is traditionally done without pesticides, but it is only recently Jhumiyas started using it. Similarly, developing agroforestry through barrier plantation would provide dual benefits of halting soil erosion and supply of marketable NTFPs. Creating semi-permanent agriculture through food forests also holds exciting potential. "Food Forest" is a system of gardening using long-lived species, particularly fruit trees of high market values. This requires low maintenance but provides goods monetary returns with positive inputs to the surrounding environment.

Besides, the use of advanced science tools such as remote sensing and GIS can supplement the limitations in traditional site-selection processes, including the collection of relevant and reliable data and improving the living standard of the locals. Lastly, developing permanent agriculture has been widely recommended in recent times, with the expectation that farmers will adopt new land-use practices. For example, the Niti Ayog recently recommended developing permanent farmland with the establishment of perennial crops, multiple cropping, crop rotations, mulching, and organic matter recycling (Aayog 2018). However, earlier proposals of permanent agriculture met with systematic failure owing to unsupported policies. For instance, the existing community-based land tenure system is not very conducive for developing permanent agriculture, particularly access to loans and other mortgage facilities are much restricted (Jamir 2015). Nonetheless, it is now evident that the government is also planning to define land use that will enable Jhumiyas to access credit and agriculture-related benefits including insurance and subsidies (Sharma 2020).

Lastly, as evident from this study, the local communities are not always aware of the imminent and long-term risks of Jhum cultivation, particularly the way it is being practiced over the last few decades. Hence, it is important to make them aware of the ecological risk of short Jhum cycle, which invariably affects their long-term survivability and the core philosophy of living of the land. It is also imperative to provide training on different sustainable technologies of mountain agriculture, including the development of agroforestry, orchard, and small water and soil harvesting structures. Developing a multi-stakeholder partnership including the traditional village councils, NGOs, aid agencies, and the local agriculture and forest office perhaps hold the key to sustainable transformation.

Conclusion

Documenting ILKPs has recently become a topic of considerable interest, as it encodes useful knowledge, belief, and practices that are otherwise unknown to the external world. Many researchers and organizations, including the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, highlighted that ILKPs are essential for sustainable and more effective environmental governance systems. In particular, an integrated approach of knowledge about modern science, technology, and indigenous and local knowledge brings up the greatest opportunity to solve some of the pressing environmental problems of today's time.

In this paper, we presented evidence of how the local communities in Nagaland traditionally managed shifting cultivation (Jhum) and how the ILKPs can ensure some degree of sustainability if fully respected and implemented. Through exploratory inquiries, our research identified fifteen major ILKPs and several minor practices with varying degrees of acceptance across different age groups. It was, however, evident that the core principles of ILKPs, laid out by ancestral systems of traditional rural institutions, are gradually fading. We identified an urgent need for policy intervention to mainstream the ILKPs in farm-level practices, and to foster future sustainability in the entire process.

Although this study narrates a specific case of Nagaland, India, we believe that the findings are important for a host of globally important agriculture sustainability issues, particularly for the remote mountain areas of S&SE Asia.

As such, the study reinstates the importance of ILKPs to maintain biodiversity and ecosystem services in these traditional mountain landscapes and provide shreds of evidence that ILKPs can successfully mediate trade-offs in agriculture and conservation conflict. Given such challenges exists across the biodiversity-rich mountain landscapes in S&SE Asia, we believe that mainstreaming ILKPs in agriculture and conservation practices can ensure future landscape sustainability and the wellbeing of the communities. We, therefore, advocate the convergence of modern scientific knowledge with traditional ecological knowledge. An integrative land use and community planning approach that builds upon the conventional landscape science and the ILKPs holds the key for future sustainability and resilience.

Acknowledgements The work was supported by the Global Environmental Facility's (GEF) Satoyama project and the Strategic Research and Development Area (JPMEERF16S11510) project financed by the Environment Research and Technology Development Fund of the Environmental Restoration and Conservation Agency of Japan (ERCA). The authors, in addition, would like to extend their sincerest thanks to the Sukhai Village council for their help, support, and involvement during the field survey.

Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

Aayog N (2018) *Report of Working Group III; Shifting Cultivation: Towards a Transformational Approach*. http://niti.gov.in/writereaddata/files/document_publication/doc3.pdf

Altieri MA (2004) Linking ecologists and traditional farmers in the search for sustainable agriculture Front Ecol Environ 2(1):35–42. https://doi.org/10.1890/1540-9295(2004)002[0035:LEATFI]2.0.CO;2

Bhagawati K, Bhagawati G, Das R, Bhagawati R, Ngachan SV (2015) The structure of Jhum (Traditional Shifting Cultivation System): prospect or threat to climate. Int Lett Nat Sci 46

Census of India (2011) *Census of India 2011 NAGALAND SERIES-14 PART XII-B District Census Handbook on Village and Town Wise Primary Census Abstract (PCA) Directorate of Census Operations Nagaland*

Chasie C (2001) *Chapter 7 Nagaland*. 241–274

Cochrane MA (2003) Fire science for rainforests. Nature 421 (6926):913–919. https://doi.org/10.1038/nature01437

DasGupta R, Hashimoto S, Gundimeda H (2019) Biodiversity/ecosystem services scenario exercises from the Asia–Pacific: typology, archetypes and implications for sustainable development goals (SDGs). Sustain Sci 14(1). https://doi.org/10.1007/s11625-018-0647-1

DasGupta R, Shaw R (2017) Perceptive insight into incentive design and sustainability of participatory mangrove management: a case study from the Indian Sundarbans. J Forestry Res 28(4):815–829. https://doi.org/10.1007/s11676-016-0355-6

Dhyani S, Bartlett D, Kadaverugu R, Dasgupta R, Pujari P, Verma P (2020) Integrated climate sensitive restoration framework for transformative changes to sustainable land restoration. Restor Ecol 28(5):1026–1031

Edake S, Sethi P, Lele Y (2019) Implementing satoyama initiative through community-conserved areas (CCAS)-a success story from nagaland, india. *International Symposium on Implementing the Satoyama Initiative for the Benefit of Biodiversity and Human Well-Being*, 86

Gay-des-Combes JM, Robroek BJM, Hervé D, Guillaume T, Pistocchi C, Mills RTE, Buttler A (2017) Slash-and-burn agriculture and tropical cyclone activity in Madagascar: implication for soil fertility dynamics and corn performance. Agriculture Ecosyst Environ 239:207–218

Goswami K, Choudhury HK, Saikia J (2012) Factors influencing farmers' adoption of slash and burn agriculture in North East India. For Policy Econ 15:146–151. https://doi.org/10.1016/j.forpol.2011.11.005

Gupta AK (2000) Shifting cultivation and conservation of biological diversity in Tripura, Northeast India. Hum Ecol 28(4):605–629

Gupta V (2005) Jhum cultivation practices of the Bangnis (Nishis) of Arunachal Pradesh. Indian J Tradit Knowl 04(1):47–56

Hauchhum R, Tripathi SK (2019) Carbon and nitrogen differences in rhizosphere soil of annual plants in abandoned lands following shifting agriculture in northeast India. Nutr Cycl Agroecosystems 113(2):157–166

Heinimann A, Mertz O, Frolking S, Christensen AE, Hurni K, Sedano F, … Poulter B (2017) *A global view of shifting cultivation: recent, current, and future extent*. https://doi.org/10.1371/journal.pone.0184479

Jamir A (2015) Shifting options: a case study of shifting cultivation in Mokokchung District in Nagaland, India. *Shifting Cultivation, Livelihood and Food Security*, 159

Kumar R, Patra MK, Thirugnanavel A, Chatterjee D, Deka BC (2016) Towards the natural resource management for resilient shifting cultivation system in eastern Himalayas. In *Conservation Agriculture*, Springer, Singapore p 409–436

Metzger JP (2003) Effects of slash-and-burn fallow periods on landscape structure. Environ Conserv 30(4):325–333. https://doi.org/10.1017/S0376892903000341

Mishra G, Francaviglia R (2021) Land uses, altitude and texture effects on soil parameters. A comparative study in two districts of Nagaland. Agriculture 11:171

Mishra G, Jangir A, Francaviglia R (2019) Modeling soil organic carbon dynamics under shifting cultivation and forests using Rothc model. Ecol Model 396:33–41

Mohapatra KP, Chandra P, Bhatt BP (2017) Agroforestry: An Integral Component of Natural Resource Conservation in the North Eastern Hill Region. In *Jhum improvement for sustaining farm livelihood and natural resource conservation in North Eastern hill region: vistas and frontiers (Ed. Prakash et al.)*.

Ostrom E (2002) Reformulating the commons. Ambient Soc 10:5–25

Ostrom E, Burger J, Field CB, Norgaard RB, Policansky D (1999) Revisiting the commons: Local lessons, global challenges. Science 284(5412):278–282. https://doi.org/10.1126/science.284.5412.278

Paul S, Tripathi AK, Roy Burman R, Panggam M, Ray SK, Kalita N, Singh AK (2017) Jhum cultivation and its consequences on forest and environment in eastern himalayan tract of india: a participatory assessment. Range Manag Agrofor 38(1):121–126

Paul S, Das TK, Pharung R, Ray S, Mridha N, Kalita N, Singh AK (2020) Development of an indicator based composite measure to assess livelihood sustainability of shifting cultivation dependent ethnic minorities in the disadvantageous Northeastern region of India. Ecol Indic 110(Feb):105934. https://doi.org/10.1016/j.ecolind.2019.105934

Priyadarshini P, Abhilash PC (2019) Promoting tribal communities and indigenous knowledge as potential solutions for the sustainable development of India. Environ Dev 32:100459

Rasul G, Thapa GB (2003) Shifting cultivation in the mountains of South and Southeast Asia: regional patterns and factors influencing the change. Land Degrad Dev 14(5):495–508. https://doi.org/10.1002/ldr.570

Rawat MS (2014) Environment and Prospects of Sustainable Development in the Zunheboto District of Nagaland1. Int J Dev Stud Res 166

Ritse V, Basumatary H, Kulnu AS, Dutta G, Phukan MM, Hazarika N (2020) Monitoring land use land cover changes in the Eastern Himalayan landscape of Nagaland, Northeast India. Environ Monit Assess 192(11). https://doi.org/10.1007/s10661-020-08674-8

Sanchez PA, Palm CA, Vosti SA, Tomich TP, Kasyoki J (2005) Alternatives to slash and burn: challenge and approaches of an international consortium. Slash-and-Burn Agriculture. The Search for Alternatives. Columbia University Press, New York, NY, p 3–37

Senotsu M, Kinny A (2016) Shifting cultivation in Nagaland: prospects and challenges. *ENVIS Bulletin on Himalyan Ecology*.

Sharma Y (2020) *Shifting cultivation may soon get legal stamp*. Economic Times. https://economictimes.indiatimes.com/news/economy/agriculture/shifting-cultivation-may-soon-get-legal-stamp/articleshow/74200736.cms

Subramanian B, Selvaraj RK, Palanisamy T, Paramanandham J, Chang L (2013) Wildlife exploitation: a market survey in Nagaland, North-eastern India. Trop Conserv Sci 6(2):241–253

Teegalapalli K, Mailappa AS, Lyngdoh N, Lawrence D (2018) Recovery of soil macronutrients following shifting cultivation and ethnopedology of the Adi community in the Eastern Himalaya. Soil Use Manag 34(2):249–257

Thomaz EL (2017) Fire changes the larger aggregate size classes in slash-and-burn agricultural systems. Soil Tillage Res 165:210–217

Thong P, Pebam R, Sahoo UK (2018) A geospatial approach to understand the dynamics of shifting cultivation in Champhai District of Mizoram, North-East India. J Indian Soc Remote Sens 46(10):1713–1723. https://doi.org/10.1007/s12524-018-0832-9

Upadhaya K, Barik SK, Kharbhih VM, Nongbri G, Debnath G, Gupta A, Ojha A (2020) Traditional bun shifting cultivation practice in Meghalaya, Northeast India. Energy Ecol Environ 5(1):34–46

Wick B, Veldkamp E, De Mello WZ, Keller M, Crill P (2005) Nitrous oxide fluxes and nitrogen cycling along a pasture chronosequence in Central Amazonia, Brazil. Biogeosciences 2(2):175–187. https://doi.org/10.5194/bg-2-175-2005