DYNAMICS OF SHIFTING CULTIVATION (JHUM) AND ITS IMPACT ON SOCIO-ECONOMIC CONDITIONS OF JHUMIAS, RECOVERY PATTERN OF VEGETATION AND SOIL IN DIFFERENT STAGES OF SUCCESSION IN NORTH-EAST INDIA

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CERTIFICATE

This is to certify that the thesis entitled ***"Dynamics of shifting cultivation (Jhum) and its impact on socio-economic conditions of Jhumias, recovery pattern of vegetation and soil in different stages of succession in north-east India"*** submitted by **Smt. Pentile Thong**, for the award of degree of **Doctor of Philosophy** in **Forestry** of Mizoram University, Aizawl, embodies the record of original investigation carried out by her under our supervision. She has duly registered and the thesis presented is worth of being considered for the award of the Ph. D. Degree. The work has not been submitted for any degree to any other University.

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DECLARATION

I, **Miss Pentile Thong**, do hereby declare that the thesis entitle **"Dynamics of shifting cultivation (Jhum) and its impact on socio-economic conditions of *Jhumias*, recovery pattern of vegetation and soil in different stages of succession in north-east India"** is the record of original work done by me, that the contents of this thesis did not form basis for the award of my previous degree or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other university/Institute.

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(PENTILE THONG)

CONTENTS

List of Tables

List of Figures

Chapter 1

General Introduction

Background

The history of shifting cultivation can be traced back to about 8000 BC in the Neolithic period which witnessed the remarkable and revolutionary change in man's mode of production of food - from hunters and gatherers to food producers. Since its inception, the term shifting cultivation is often used interchangeably with the terms 'slash-and-burn' or 'jhum' but it is invariably identified with rotation of fields rather than rotation of crops. In this form of agriculture, the forest is slashed and burnt on site, which is then planted with crops varying from food grains and vegetables to tubers and fruits. Eventually when all the crops are harvested, the site is left fallow to reclaim its natural forest cover while the farmer move on to clear fresh forest land. Meanwhile, while it lies fallow, the farmer may use it to collect numerous food, timber and non timber forest products. Once the fallow land regains its fertility, the farmer come back to the same piece of land for cultivation depending on ethnicity, population and land ratio. This intervening duration between two successive slashing is termed as jhum cycle/ crop-fallow rotation cycle. The ideal length of the jhum cycle depends on the quality of the land, which is determined by the type of vegetation, steepness, altitude, and aspect. At higher elevations, more time is needed for forest regeneration, so fallows should be longer.

Over the past years, shifting cultivation was considered environmentally suitable when the fallow period was for 15–20 years. Then the fallow period was long enough to regenerate soil capacity and vegetation cover (Ramakrishnan and Toky, 1981; Roder et al., 1997). Gradually growing population and government control over forest have in numerous ways compelled the farmers to shorten the fallow period to 2–3 years (Tiwari, 2003; Fujita and Phanvilay, 2008). However, no relevant work has been done to substantiate these claims and analyse the socio-economic condition of the farmers which contributes to the dynamic nature of shifting cultivation in North-East India. Furthermore, since this practice involves a continuous cycle of clear-felling and regeneration, jhum fallow sites provide an opportunity to understand the secondary succession patterns and contribution of fallow time to site productivity.

Extent of shifting cultivation: Global, National and North-East India

Shifting Cultivation is said to be practiced throughout the tropics and subtropical highlands of Asia, Africa and Latin America comprising of about 64 developing countries (Whitmore, 1984). About one-third of the total agricultural area in South East Asia is reported to be under shifting cultivation (Dobby, 1950). It was widespread in the temperate zones of the Mediterranean and Northern Europe until the 19th century, as well as in the Southwestern and Northeastern pine woodlands of North America until the 1940s (Vergara, 2001). Although exact global figure of people engaged on shifting cultivation is difficult to access, it is estimated that in the 1980s roughly 300 million to 500 million people were dependant on the practice. The practice is prevalent among the ethnic communities of Madagascar, Mexico, Rhodesia, Burma, Bhutan, China, India, Indonesia, Nepal, Papua New Guinea, Philippine, Sri Lanka, Korea, Thailand and Vietnam

Keeping in mind the global scenario, precise figures about the total area under shifting cultivation or the total number of families involved in shifting cultivation in India remain unclear as well. Studies reported that jhum is the main economic activity for 0.44 million tribal families and constitutes 83.73 % of the total shifting cultivation area in India (Mandal, 2011; Yadav, 2013). Furthermore, Satapathy et al., (2003) estimated about 607,536 families to be engaged in shifting cultivation in the country covering about 22.78 lakh hectares with a per capita holding of 1.06 hectares. Eswaraiah (2003) also estimated about 10 million hectares of tribal land across 16 states in India to be under shifting cultivation.

Recent studies reported the decline in area under shifting cultivation in the region (Chakraborty et al., 2015; Sarma et al., 2015; Nongkynrih et al. 2018; Rao et al., 2018; Riahtam et al., 2018; Thong et al., 2018a, 2019a; Das et al., 2021). Shifting cultivation nevertheless contributes 86% of the total cultivated land in North-East India. Till date there is no definite reliable information on the extent of shifting cultivation in terms of area covered or number of persons engaged in it. However, as per an old ICAR review the total estimated area under shifting cultivation in this region was 5.42 lakh hectares and about 26.441 lakh tribal populations were engaged in it. Report of the Dhebar Commission revealed that nearly 5.41 lakh hectares of area are annually covered by shifting cultivation and about 25.89 lakh tribal populations are dependent on it.

Perspectives on shifting cultivation

There are divergent opinions about the effects of shifting cultivation on the environment. A section of intellectuals believe that continuance of shifting cultivation with necessary and effective reforms can do little damage to soil erosion as high humidity and heavy rainfall in the region do not permit the soil to remain uncovered for long (Cherrier et al., 2018; Erni, 2015). In addition, jhum is well adapted to the moist and hilly terrain of the region, its multi-cropping nature and cultural importance to the indigenous tribes over the centuries has evolved jhum as a source of livelihood and food security (Thong et al., 2018b). Yet, several studies emphasized on the harmful effects of shifting cultivation, including air pollution and greenhouse gas emission due to burning, soil and nutrient erosion, deforestation causing habitat loss of many wildlife (Frizano et al., 2003; Denich et al., 2005; Lawrence et al., 2010). From the modern economist point of view, the disadvantage of jhum exerts negative influences on the economy (Kalita et al, 2017), the other school continues to support shifting cultivation viewing that the practitioners of shifting cultivation are part of conservation (Das, 2006; Hazarika, 2017; Munda et al., 2010).

Due to its negative impact on the environment, parts of South and South-East Asian countries have developed policies to replace shifting cultivation with more productive and sustainable land use systems (Fox et al., 2009; Van Vliet et al., 2012). However, few scientists reported the benefits of shifting cultivation and replacing it with alternative land use systems have led to various detrimental impacts to the environment (Ziegler et al., 2011). For example, replacement of jhum by intensive agriculture systems have resulted in increased in soil erosion and landslides, reduced in water quality by the use of fertilizers and pesticides, and stream desiccation due to water extraction (Sidle et al., 2006; Ziegler et al., 2004, 2009). Also, the replacement of long fallow period jhum with continuous cycle of annual cropping resulted in declined of more than 90% of aboveground carbon stock (Bruun et al., 2009).

Lately, it has been realised the fact that jhum cannot be stopped altogether, and therefore it is necessary to make the process more productive in order to accommodate and sustain the growing populace dependent on shifting cultivation. This can be achieved by examining the real balance in light of experience and data, recognise traditional knowledge, support traditional social security and equity for the poor, develop a clear path for real bottom-up development with a facilitative government, learn from innovations throughout the region and to motivate rural transformation.

Scope of the study

Researchers, especially in ecological sciences, have discussed about regional diversity in the practice of jhum cultivation in the North-Eastern States in India. This regional diversity can be regarded as indication of the innovative capacities of these communities. There is, however, very little attempt to study the nature and dynamics of innovative processes of cultivation by these communities (jhumias). The current study attempts to understand the dynamics of shifting cultivation with respect to the socio-economic condition of the jhumias as well as to analyse the recovery pattern of vegetation and soil nutrient status at different stages of succession after abandonment.

The findings will contribute towards understanding of the dynamics of forest cover and soil nutrient in areas following shifting cultivation.

Objectives

With a view to understand the dynamism of shifting cultivation fields in North-East India, the present study was taken up with the following objectives:

1. Spatial and temporal dynamics of shifting cultivation in North-East India based on time-series satellite data
2. Influence of socio-economic factors on the existing trend of shifting cultivation practice
3. Socio-economic vulnerability assessment of shifting cultivators (jhumias) amidst the changing climate in North-East India
4. Recovery pattern of vegetation following shifting cultivation
5. Soil nutrient status at different stages of succession after abandonment of jhum

Chapter 2

Review of literature

Spatio-temporal dynamics of shifting cultivation

Early research on shifting cultivation supported by remote-sensing technologies began in the 1980s. In these studies, multi-source and multi-temporal satellite data were used for its mapping. The most commonly used satellite data are Landsat imageries as it freely available with long acquisition record (Petropoulos et al., 2011). Globally, multiple studies have been conducted wherein different sensors of Landsat were utilised. Jakovac et al. (2017) have used Landsat time series to estimate fallow periods and patterns of its intensification in Amazonia. Another, case study on shifting cultivation using Landsat time series study data was conducted in Brazil by Dutrieux et al. (2016). Vast repository of Landsat based studies have also been observed in the Asian continent. For instance, Peng et al. (2018) detected and monitored the extent and area of newly-burnt plots of shifting cultivation in Montane Mainland Southeast Asia (MMSEA). Leisz and Rasmussen (2012) also mapped the fallow lands in Vietnam’s north-central mountainous area using yearly TM imagery and a land-cover succession model. Furthermore, Shimizu et al. (2018) conducted patch-based assessments and characterization of shifting cultivation using time series images in Myanmar. Multiple studies on remote sensing and Geographic Information System (GIS) aspect of shifting cultivation have been carried out in Laos. As such, Inoue et al. (2007, 2008) traced the slash and burn land-use history and analysed the reflectance characteristics of land surfaces in slash and burn ecosystem. Yamamoto et al. (2009) further spatially identified the crop-fallow rotation cycle in northern Laos. Chowdary et al. (2012) used supervised classification method to monitor the alternation of cropping and fallow fields and their transformation to and from forest in Oudomxay Province in northern Laos. A texture-based land cover classification for the delineation of a shifting cultivation landscape was conducted by Hurni et al. (2013). To understand the intensity of swidden use and fallow forest recovery, Chenhua et al. (2015) used a decision tree classification approach followed by the analysis of spatio-temporal changes in shifting cultivation. Rao et al. (2018), Thong et al. (2018a, 2019a), Kurien et al. (2019) and Pasha et al. (2020) are among the few studies conducted in the North-East region of India using Landsat time series data wherein the area under jhum, spatial distribution of jhum plots with respect to topography, trend of shifting cultivation and crop-fallow rotation cycle are assessed.

Socio-economic perspectives on shifting cultivation

Generally, jhum lands are scattered in the forest areas at medium to high slope gradient. Owing to high soil erosion, soil fertility is considerably low and as a result, output from shifting cultivation is relatively low. Jhum cultivation systems are generally productive, making efficient use of resources, ensuring ecological sustainability and food security, thus providing a social safety net for local communities. It is an ecologically and economically viable system of agriculture as long as population densities are low and jhum cycles are long enough to maintain ecological balance. In the current scenario, inspite of its low production and yield, the jhumias enjoy practicing shifting cultivation, as it has become their socio-cultural activity and the way of life.

Nevertheless, nowadays, this traditional socio-ecological system is undergoing a rapid transformation. This transformation, from subsistence to market oriented agriculture production, has been accelerated by the increasing regional and global economic integration together with the rapidly expanding major transportation infrastructure (Thongmanivong et al. 2009; Seidenberg et al. 2003; Padoch et al. 2007; World Bank 2008). Stone (2001) reported that the socio-cultural and economic systems influenced land-use decisions of two neighbouring communities in Central Nigeria. Similarly, Brookfield (2001) and Lambin et al. (2001) have both shown the importance of economic influence from market in shaping agricultural systems. Dharumarajan et al. (2017) stated that the biophysical characteristics of farmland and socio-economic conditions of farmers are responsible for the increasing fallow period, thereby maintaining the jhum cycle.

Few studies have been conducted on the socio-economic parameters influencing the existing jhum practice in North-East India. Thong et al. (2018b, 2019b) revealed that the age of household head, annual income and family size influenced the existing jhum practice while socio-economic factors namely education and occupation significantly contributed to the decreasing trend of area under shifting cultivation in

Champhai. Similarly, Datta et al. (2014) stated that the education level of the household head, family size, number of family members involved in jhum, area under jhum, annual income, fallow period, livestock possession and material possession had positive significant relationships with the livelihood status of the jhumias in Tripura and thus, could be manipulated to improve the livelihood status of tribal people.

Socio-economic vulnerability status of shifting cultivators

The vulnerability of a community to the impact of hazards is determined by the physical, social, economic, and environmental factors or processes, and is also location and hazard-specific (UNISDR, 2017). Many direct and proxy indicators have been used to assess the socio-economic vulnerability, and these indicators vary from place to place and time to time (Liu et al. 2016; Sahoo and Bhaskaran, 2018; Kantamaneni et al. 2019). Das (2013) studied regional variation in potential vulnerability in Indian Agriculture to climate change where the Socio-Economic Vulnerability Index was calculated using indicators like irrigation strength, percentage of people living in poverty, percentage of agricultural workers among total workers, and literacy rate. Kuchimanchi et al. (2019) incorporated a community engaging vulnerability assessment tool to explore the climate risks and vulnerabilities of different social groups. Insights indicate that vulnerability is socially differentiated across farmer categories and social groups. Malakar and Mishra (2017) assessed the socio-economic vulnerability to climate change focused on a city-level index-based approach in which indicators of socio-economic vulnerability were compiled and segregated into major components like infrastructure, technology, finance, social and space. Farmers' perception of climate change and adaptation decisions was conducted by Singh (2020) using a multi-stage sampling technique to select study sites and respondents. Study findings revealed that variability in temperature and rainfall had adversely affected the livelihoods of farmers. Swami and Parthasarathy (2021) studied dynamics of exposure, sensitivity, adaptive capacity and agricultural vulnerability at district scale for Maharashtra, India and their findings show that few districts were vulnerable despite being least exposed to climate variability signifying the contribution of sensitivity and adaptive capacity parameters towards their vulnerability. A comprehensive analysis using multiple physical-socio-economic variables have also been attempted to identify the vulnerability (Mullick et al., 2019). However, there is very little knowledge/analysis on socio-economic vulnerabilities at micro (village/ward) level considering predominantly the socio-economic variables instead of the highly location-specific physical vulnerability parameters (Hoque et al., 2019). Till date, no attempt has been made to assess the vulnerability of jhumias to the changing climate.

Community characteristics of vegetation on fallow lands following shifting cultivation

Studies show great variation in the changes of plant density along the succession trajectory. Studies carried out in North-East India reported an increase in the stem density of tree stratum with increasing fallow gradient while the shrub and herb densities decreases (Tripathi et al., 2015; Thong et al., 2016, 2020; Gogoi et al., 2020). On the other hand, in Mizoram species density of tree increases at the initial stage of succession but then decline subsequently (Hauchhum and Singson, 2020). In all the above studies, the basal area of trees however increased with fallow age. Although species' responses to succession are deemed to be highly individualistic (Toledo and Salick 2006), a similarity among age classes was found by a number of researches. Intermediate age classes were found to be closer in species composition (Toledo and Salick 2006, Tripathi et al., 2015; Thong et al., 2020), however the species composition in young fallows evidently differ from the old fallow (Breugel et al., 2007; Thong et al., 2020). The variation of species richness and diversity is correlated with the fallow age and topographical parameters namely slope, aspect and elevation of the fallow site (Zhang and Dong, 2010; Thong et al., 2020). Chazdon et al. (2007) suggested that the rate of forest regeneration is affected by the complex interactions of different anthropogenic and natural factors. Similarly, a number of researchers (Williams-Linera and Lorea 2009; Molina Colon and Lugo 2006; Romero-Duque et al. 2007) stated that human disturbance and other environmental factors are likely to have an impact on the succession process. Time since last abandonment was the key factor for the restoration process following shifting cultivation. Besides, the slope, aspect and elevation of the fallow stand were also found to influence the regeneration process (Zhang and Dong, 2010; Klanderud et al., 2010; Tran et al., 2011; Thong et al., 2020).

Soil health status at different fallow period

The soil nutrient build up during the initial stages of ecosystem succession is also a gradual process that would favour the growth of plant species that are shade intolerant or low in nutrient efficiency. The evaluation of soil quality, from plot to regional scale, is based on the use of selected physical, biological and chemical indicators, sensitive to land-use changes, soil disturbance and/or any input into the soil system (Brejda et al. 2000). Many types of soil quality index were developed to assess soil quality under different land uses (Marzaioli et al. 2010), under land use change (Li et al. 2013), in different climate condition (Sánchez-Navarro et al. 2015), as well as in different regions of the world (Nortcliff 2002). Although many studies included some regions of India (Mohanty et al. 2007; Masto et al. 2008, 2009; Ayoubi et al. 2011), only a few of them (Singh et al. 2014) focused their attention on soil quality assessment in the North-East region of Indian Himalaya (NEH). The assessment of the impacts on soil caused by shifting cultivation, with a focus on maintaining and improving soil quality is crucial point for the development of a strategy to promote agricultural productivity and the environment quality in the northeast of the Himalayas (Das et al. 2016). Studies in the tropics have shown significant changes in soil organic carbon following conversion of natural forest to cropland, and these changes have been shown to affect soil fertility (Brown and Lugo, 1990; Ramakrishnan et al., 2003). Widiyatno et al. (2017) reported from Indonesia that the available phosphorous content was significantly different between the plot that had been fallow for one year and the rest of the plots. It was concluded that changes in vegetation composition did not affect the status of soil nutrients in the young fallow plots, which can support the growth of late-succession. In addition, a global meta-analysis on the dynamics of soil chemical properties in shifting cultivation systems in the tropics (Filho et al., 2015) reported that pH values increase under shifting cultivation system conditions, while Total N and C content are significantly reduced. No significant impacts are observed on CEC. The findings on pH and CEC further support the position from researchers who argued for the sustainability of shifting cultivation system and highlight the importance of evaluating the soil system as a soil/vegetation complex. It was also found that the soil chemical properties under shifting cultivation systems scenarios are better conserved and more readily recoverable, provided there is a rather longer fallow period than has been traditionally employed.

Chapter 3

Study site description

Introduction

Geographically, North-East region of India stretches between 21°50"and 29°34" N latitude and 85°34" and 97°50" E longitude. This region covers a geographic area of 2,55,143 sq. km and holds a population of 38 million, which is 8% and 3.85% of area and population of whole India, respectively. Most marked characteristics of this region are its large rural population (89.86%), huge tribal inhabitants (Irshad Ali and Das, 2003) and wide area covered under forests (63.9%) (Mishra and Sharma, 2001). The average annual rainfall in the region varies from 2000 to 4000 mm, received mainly from south-west monsoon from middle of May and continues till October. North-East India shows great variation in temperature throughout the year from 15˚C to 32˚C in summer and 0˚C to 26˚C in winter. The study was conducted in two districts of three states in North-East India which were prone to shifting cultivation. The selected districts were Champhai and Aizawl in Mizoram, Ukhrul and Chandel in Manipur, and Mon and Wokha in Nagaland (Figure 3.1). According to Wasteland Atlas of India, 2011 the percentage of shifting cultivation area with respect to total geographical area of Champhai, Aizawl, Ukhrul, Chandel, Mon and Wokha districts were 6.16, 5.55, 4.49, 21.73, 14.20 and 5.82 respectively.

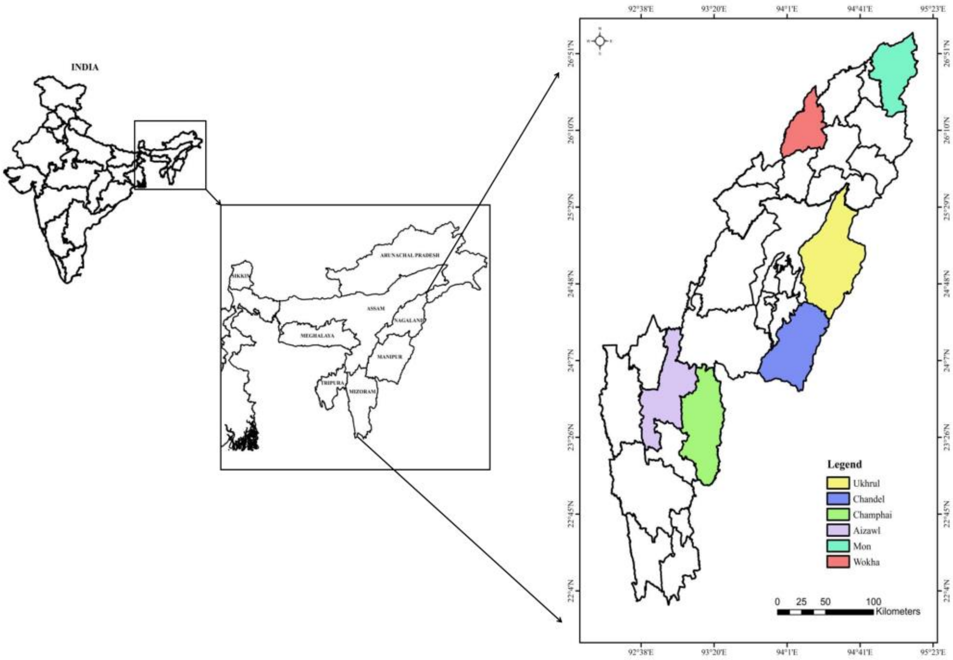


Figure 3.1: Map of India showing the location of the study area

Study area:

1. Champhai and Aizawl districts of Mizoram:

Mizoram lies between 21°58´ to 24°35´ N latitude and 92°15´ to 29°29´ E longitude and covers an area of approximately 21,087 Km^2. Champhai and Aizawl districts are situated in the North-Central and Eastern part of the state respectively. These districts experience a moderate climate conditions due to its sub-tropical location and high elevation ranges. Champhai is spread over an area of 3185 km^2 up to an elevation of 1678 m a.s.l. The average mean summer temperature (April to June) is 23.5°C and average mean winter temperature (November to February) is 15.7°C with an average annual rainfall of 1814 mm. The district has colluvial type of soil with sandy loam to clay texture and acidic in nature (pH ranges from 4.5 to 6.5). Aizawl district covers an area of 3577 Km^2 and is situated at an elevation of 1132 m a.s.l. The average annual rainfall of the district is about 1849 mm with an average summer temperature between 20-30° C and average winter temperature of 11-21°C. Aizawl soil is of loose sedimentary type with clay loam to clay texture and pH ranging from 4.6 to 6.1. The topographical features of Champhai and Aizawl districts are represented in Figure 3.2.

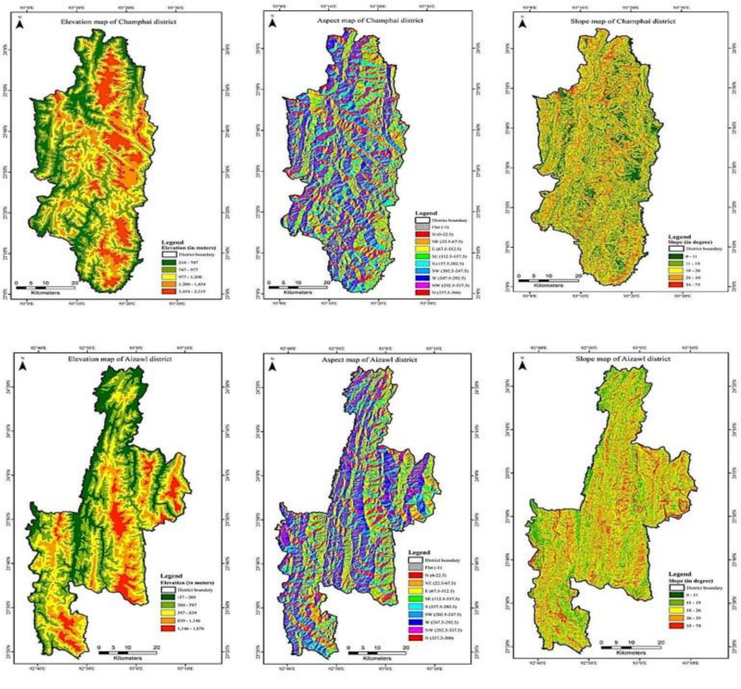


Figure 3.2: Elevation, Aspect and Slope map of Champhai and Aizawl

2. Ukhrul and Chandel districts of Manipur:

Manipur lies between 23°83´N to 25°68´N latitude and 93°03´E to 94°78´E longitude, comprising of 1820 km² of valley area and 20,507 km² of hill area. Ukhrul and Chandel are among the ten hill districts situated in the north-eastern and south-eastern part of the state respectively. The subtropical climate of this region is affected by the southwest and northeast monsoons with distinct rainy (June to September) and dry (November to February) seasons. Ukhrul has an area of 4544 Km² and is located at an elevation of 1662 m a.s.l. The average annual temperature of Ukhrul is 15.5°C with annual rainfall of about 1616 mm. The district has alluvial, lateritic black regur and red ferruginous type of soil. Chandel covers an area of 3313 Km² and is situated at an elevation of 957 m a.s.l. The average annual temperature of Chandel is 20.6°C with annual rainfall of about 1877 mm. The district has lateral sandy loam, reddish in colour and acidic type of soil (pH = 4 to 4.5). The topographical features of Ukhrul and Chandel districts are represented in Figure 3.3.

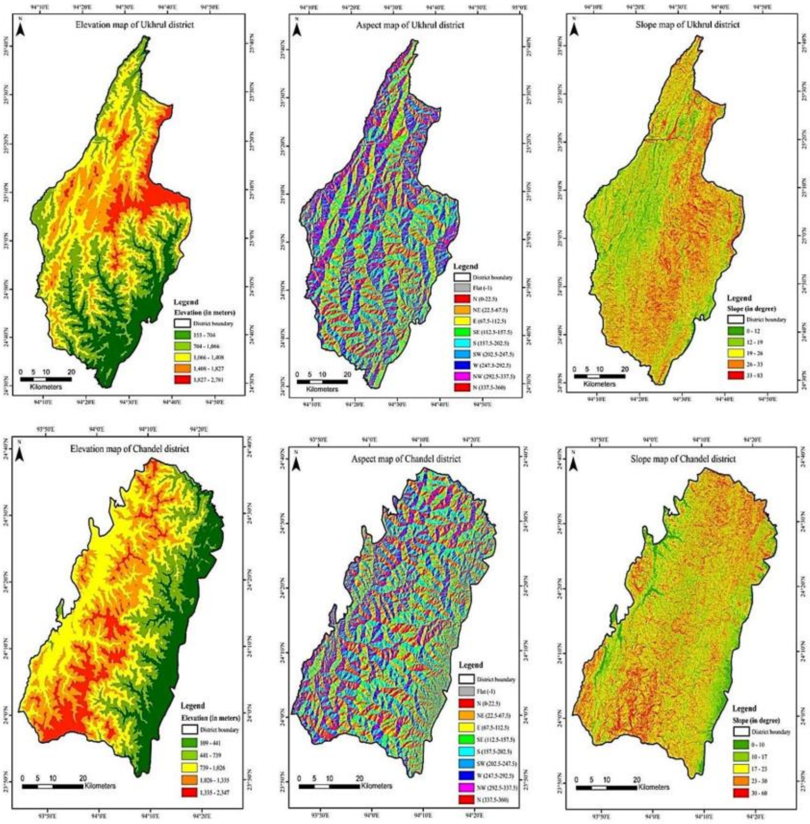


Figure 3.3: Elevation, Aspect and Slope map of Ukhrul and Chandel

3. Mon and Wokha districts of Nagaland:

Nagaland lies between 25°06´N to 27°04´N latitude and 93°20´E to 95°15´E longitude, covering an area of 16579 Km². Mon and Wokha districts are situated in the Northernmost and mid Western part of the state. The southwest monsoon originating from the Bay of Bengal and the Arabian Sea directly controls the climate of these districts. Mon covers an area of about 1768 km² and elevation of 898 m a.s.l. The average annual temperature and rainfall of Mon is 24.4°C and 2000 – 3000 mm respectively. Various soil types were found in the district as the provenance differs widely, however, the major type of soil is red sandy soil. The total geographical area of Wokha is 1628 Km² and is situated at an elevation of 1313 m a.s.l. The average annual rainfall of the district ranges from 2000 to 2500 mm with an average summer temperature between 16 - 32° C which falls to 2°C in winter. The district is dominated by recent and older alluvial soil and residual soil. The topographical features of Mon and Wokha districts are represented in Figure 3.4.

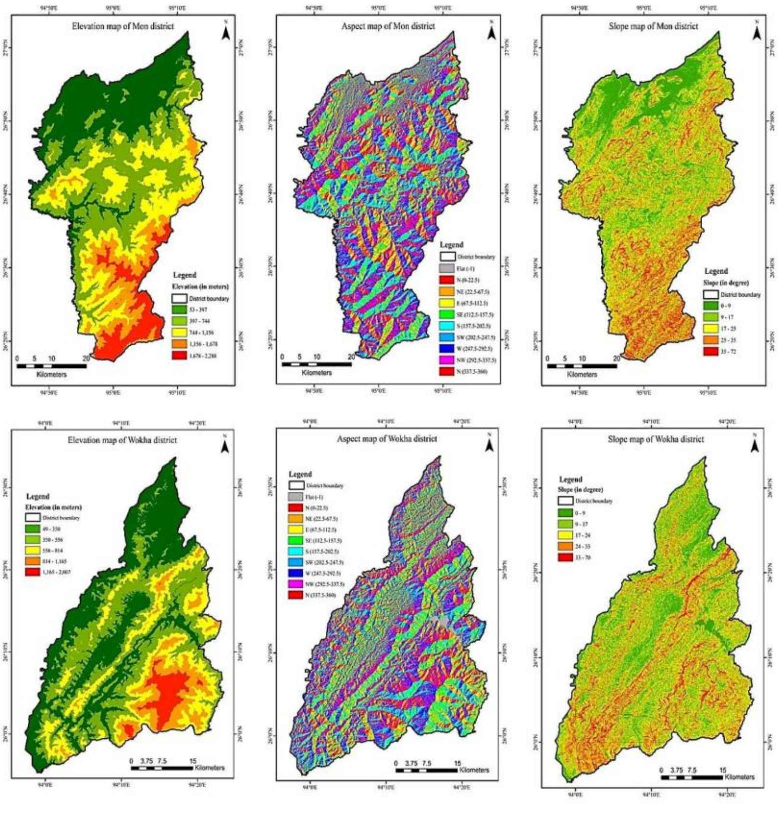


Figure 3.4: Elevation, Aspect and Slope map of Mon and Wokha

Chapter 4

Spatial and temporal dynamics of shifting cultivation in North-East India based on time-series satellite data

4.1 Introduction

Shifting cultivation (locally known as Jhum) is a traditional agricultural practice wherein the forest is slashed and burnt on site, which is then planted with crops varying from food grains and vegetables to tubers and fruits. Eventually when all the crops are harvested, the site is left fallow to reclaim its natural forest cover while the farmers move on to clear fresh forest land (Momin, 1995; Yadav, 2013). Once the fallow land regains its fertility, the farmers come back to the same piece of land for cultivation. This intervening duration between two successive slashing is termed as jhum cycle which is influenced by population pressure, terrain, angle slope, soil and average annual rainfall. The shifting of jhum fields from one site to another result in a dynamic landscape (Zimmermann and Eggenberg, 1994), consisting of a mosaic of jhum fields, different aged fallows and mature forest which can be under constant change (Fox et al., 2000; Metzger, 2003; Brown, 2006).

Over the past few years, the jhum cycle has also been reported to be decreasing from 10–15 years to 4–5 years but no relevant work has been done to substantiate these claims. With the emergence of remote sensing technology, the mapping and monitoring of jhum have been effectively conducted with much validity over time and space (Thong et al., 2018a, 2019a). Shifting cultivation landscape is distinguished by spatial pattern of different stages of jhum plots and forests (Hett et al., 2011). Time series analysis is used to retrieve the prevalence of slash and burn events and the duration of fallow period (Jakovac et al., 2015). By digitizing the different stages of jhum of each year and performing a post-classification comparison, the crop-fallow rotation cycle/ jhum cycle can be assessed (Inoue et al., 2010). Freely available Landsat imagery with long acquisition record supports its wide use in satellite time series analysis (Petropoulos et al., 2011). However, particulars about the extent and shifting nature of jhum especially on a regional level still remain insufficient. In fact, no such studies have been conducted in hilly areas of North-East India where shifting cultivation is prevalent. This may be because of the complexity in differentiating forest and fallow following shifting cultivation in the mountainous region. Furthermore, shifting cultivation which involves the rotation of plot causes difficulty in tracing the landscape where jhum prevails (Hurni et al., 2013).

As per the Wasteland Atlas report (2005, 2010, 2019), there has been a decreasing trend in the area under jhum in Ukhrul and Wokha, yet the jhum area of other 4 districts vary with each assessment. While district census reports showed population growth in the study areas, keeping in view the findings of National Remote Sensing Centre and Census Commission of India, an attempt was made to examine the relation between population and spatial distribution of jhum at Rural Development (R.D) Block level of each district.

Therefore, this chapter is an approach to (i) assess the status of shifting cultivation in the study areas from 1999 to 2017/2018/2019, (ii) ascertain the existing cropping period, fallow period and the crop-fallow rotation cycle/jhum cycle, and (iii) relate the intensity of shifting cultivation with the human population density over the study period. Understanding the dynamic nature of shifting cultivation will contribute towards sustainable forest management and proper planning of land management strategies in relation to socio-economic, cultural ethics and food security of the jhumias.

4.2 Materials and Methods

4.2.1 Selection of satellite imagery

In accordance to the typical calendar of jhum in North-East India, forest vegetation is slashed at the onset of the dry season and burnt three or four weeks following slashing depending upon the dryness of the debris. The period from slashing to burning can be easily detected by satellite imagery (Bhandari et al., 2004). Therefore, Landsat satellite images for the period 1995 – 2017/2018/2019 were downloaded comprising of Landsat TM, ETM+ and OLI with spatial resolution of 30 m. The entire study area was covered in 6 scenes and each year’s image was chosen for those during January to early April. The specification of Landsat satellite images used for the present study is presented in Table 4.1.

Table 4.1: Details of the satellite imagery used for the present study

Sl. no	Image type	Path/ row	Acquisition date (dd-mm-yyyy)	Sl. no	Image type	Path/ row	Acquisition date (dd-mm-yyyy)
1.	Landsat TM	135/41	07-01-1995	75.	Landsat TM	135/44	23-01-1995
2.	Landsat TM	135/41	11-02-1996	76.	Landsat TM	135/44	11-02-1996
3.	Landsat TM	135/41	01-03-1997	77.	Landsat TM	135/44	01-03-1997
4.	Landsat TM	135/41	04-03-1998	78.	Landsat TM	135/44	16-02-1998
5.	Landsat TM	135/41	03-02-1999	79.	Landsat TM	135/44	07-03-1999
6.	Landsat TM	135/41	22-02-2000	80.	Landsat TM	135/44	17-03-2000
7.	Landsat TM	135/41	12-03-2001	81.	Landsat TM	135/44	05-04-2001
8.	Landsat ETM$^+$	135/41	07-03-2002	82.	Landsat TM	135/44	08-04-2002
9.	Landsat ETM$^+$	135/41	13-01-2003	83.	Landsat TM	135/44	22-02-2003
10.	Landsat TM	135/41	17-02-2004	84.	Landsat ETM$^+$	135/44	25-02-2004
11.	Landsat TM	135/41	02-01-2005	85.	Landsat TM	135/44	19-02-2005
12.	Landsat TM	135/41	06-02-2006	86.	Landsat TM	135/44	06-02-2006
13.	Landsat TM	135/41	29-03-2007	87.	Landsat TM	135/44	25-02-2007
14.	Landsat TM	135/41	28-02-2008	88.	Landsat TM	135/44	28-02-2008
15.	Landsat TM	135/41	14-02-2009	89.	Landsat TM	135/44	06-01-2009
16.	Landsat TM	135/41	01-02-2010	90.	Landsat TM	135/44	01-02-2010
17.	Landsat TM	135/41	04-02-2011	91.	Landsat TM	135/44	04-02-2011
18.	Landsat ETM$^+$	135/41	18-03-2012	92.	Landsat ETM$^+$	135/44	30-01-2012
19.	Landsat ETM$^+$	135/41	05-03-2013	93.	Landsat ETM$^+$	135/44	05-03-2013
20.	Landsat ETM$^+$	135/41	24-01-2014	94.	Landsat TM	135/44	28-02-2014
21.	Landsat ETM$^+$	135/41	14-01-2015	95.	Landsat ETM$^+$	135/44	11-03-2015
22.	Landsat OLI	135/41	05-03-2016	96.	Landsat OLI	135/44	18-02-2016
23.	Landsat OLI	135/41	04-02-2017	97.	Landsat OLI	135/44	04-02-2017
24.	Landsat OLI	135/41	22-01-2018	98.	Landsat TM	136/43	19-03-1995
25.	Landsat OLI	135/41	02-02-2019	99.	Landsat TM	136/43	05-03-1996
26.	Landsat TM	135/42	07-01-1995	100.	Landsat TM	136/43	24-03-1997
27.	Landsat TM	135/42	11-02-1996	101.	Landsat TM	136/43	27-03-1998
28.	Landsat TM	135/42	01-03-1997	102.	Landsat TM	136/43	26-02-1999
29.	Landsat TM	135/42	04-03-1998	103.	Landsat TM	136/43	13-02-2000
30.	Landsat TM	135/42	18-01-1999	104.	Landsat TM	136/43	30-01-2001
31.	Landsat TM	135/42	05-01-2000	105.	Landsat ETM$^+$	136/43	26-02-2002
32.	Landsat TM	135/42	08-02-2001	106.	Landsat ETM$^+$	136/43	28-01-2003
33.	Landsat ETM$^+$	135/42	02-01-2002	107.	Landsat ETM$^+$	136/43	08-03-2004
34.	Landsat ETM$^+$	135/42	21-01-2003	108.	Landsat TM	136/43	10-02-2005
35.	Landsat TM	135/42	04-03-2004	109.	Landsat TM	136/43	13-02-2006
36.	Landsat TM	135/42	18-01-2005	110.	Landsat TM	136/43	04-03-2007
37.	Landsat TM	135/42	06-02-2006	111.	Landsat TM	136/43	06-03-2008
38.	Landsat TM	135/42	29-03-2007	112.	Landsat TM	136/43	21-02-2009
39.	Landsat TM	135/42	15-03-2008	113.	Landsat TM	136/43	08-02-2010
40.	Landsat TM	135/42	14-02-2009	114.	Landsat TM	136/43	11-02-2011
41.	Landsat TM	135/42	01-02-2010	115.	Landsat ETM$^+$	136/43	22-02-2012
42.	Landsat TM	135/42	04-02-2011	116.	Landsat ETM$^+$	136/43	24-02-2013
43.	Landsat ETM$^+$	135/42	30-01-2012	117.	Landsat TM	136/43	19-02-2014
44.	Landsat ETM$^+$	135/42	05-03-2013	118.	Landsat ETM$^+$	136/43	21-01-2015
45.	Landsat ETM$^+$	135/42	04-02-2014	119.	Landsat OLI	136/43	24-01-2016
46.	Landsat ETM$^+$	135/42	22-01-2015	120.	Landsat OLI	136/43	27-02-2017
47.	Landsat OLI	135/42	17-01-2016	121.	Landsat TM	136/44	30-01-1995
48.	Landsat OLI	135/42	28-01-2017	122.	Landsat TM	136/44	18-02-1996
49.	Landsat OLI	135/42	22-01-2018	123.	Landsat TM	136/44	24-03-1997

50.	Landsat OLI	135/42	25-01-2019	124.	Landsat TM	136/44	27-03-1998
51.	Landsat TM	135/43	23-01-1995	125.	Landsat TM	136/44	26-02-1999
52.	Landsat TM	135/43	11-03-1996	126.	Landsat TM	136/44	28-01-2000
53.	Landsat TM	135/43	01-03-1997	127.	Landsat TM	136/44	19-03-2001
54.	Landsat TM	135/43	04-03-1998	128.	Landsat ETM$^+$	136/44	30-03-2002
55.	Landsat TM	135/43	23-03-1999	129.	Landsat ETM$^+$	136/44	01-03-2003
56.	Landsat TM	135/43	22-02-2000	130.	Landsat ETM$^+$	136/44	08-02-2004
57.	Landsat ETM$^+$	135/43	05-04-2001	131.	Landsat TM	136/44	10-02-2005
58.	Landsat ETM$^+$	135/43	07-03-2002	132.	Landsat TM	136/44	28-01-2006
59.	Landsat ETM$^+$	135/43	10-03-2003	133.	Landsat TM	136/44	04-03-2007
60.	Landsat TM	135/43	04-03-2004	134.	Landsat TM	136/44	06-03-2008
61.	Landsat TM	135/43	08-04-2005	135.	Landsat TM	136/44	21-02-2009
62.	Landsat TM	135/43	10-03-2006	136.	Landsat TM	136/44	08-02-2010
63.	Landsat TM	135/43	13-03-2007	137.	Landsat TM	136/44	11-02-2011
64.	Landsat TM	135/43	28-02-2008	138.	Landsat ETM$^+$	136/44	22-02-2012
65.	Landsat TM	135/43	02-03-2009	139.	Landsat ETM$^+$	136/44	24-02-2013
66.	Landsat TM	135/43	21-03-2010	140.	Landsat TM	136/44	19-02-2014
67.	Landsat TM	135/43	08-03-2011	141.	Landsat ETM$^+$	136/44	21-01-2015
68.	Landsat ETM$^+$	135/43	03-03-2012	142.	Landsat OLI	136/44	24-01-2016
69.	Landsat ETM$^+$	135/43	05-03-2013	143.	Landsat OLI	136/44	27-02-2017
70.	Landsat OLI	135/43	16-03-2014				
71.	Landsat OLI	135/43	19-03-2015				
72.	Landsat OLI	135/43	18-02-2016				
73.	Landsat OLI	135/43	17-02-2017				
74.	Landsat OLI	135/44	11-03-2018				

4.2.2 Pre-processing of satellite images

The freely available ortho-rectified Landsat Satellite images (UTM/ WGS1984 Projection) by United States Geological Survey (USGS) were obtained from the website (www.glovis.usgs.gov). Near-Infrared, Red and Green bands were used to generate False Colour Composite (FCC) as these bands mainly contain information related to agriculture and forest for geospatial management (Myint and Lam, 2005). Band 4 3 2 combination was used for Landsat TM, ETM+ and 5 4 3 for Landsat OLI.

4.2.3 Image interpretation

On-screen visual interpretation of each year's satellite imagery from 1999 to 2017 was performed for Ukhrul and Chandel, 1999 to 2018 for Champhai and Aizawl, and 1999 to 2019 for Mon and Wokha. Different stages of jhum cultivation, ie Current jhum, 2nd year jhum, 3rd year jhum, 4th year jhum and abandoned jhum were digitized based on visual elements and physiography of the districts in ArcGIS 10.2.2 version. The current jhum plot of each year was also cross-checked with the previous year image to validate if it was newly slashed or 2nd year jhum plot. Furthermore, reflectance spectra of different land use types in shifting cultivation landscape were derived in NIR, R and G bands for differentiating the spectral characteristics of these land use categories. Clear differences in spectra were visible in burnt jhum, unburnt jhum and healthy forest. Burnt jhum displayed monotonous reflectance through the whole wavelength region. Unburnt jhum showed the maximum reflectance in green and red region with healthy forest in near-infrared region. Scrublands did not show any distinct reflectance in comparison to other land use types. Depending on the spectral signatures of the different land use, the interpretation key to distinguish the different stages of shifting cultivation was generated (Table 4.2).

Table 4.2: Interpretation key for jhum land mapping

Phase of jhum	Tone	Texture	Pattern	Association
Current jhum	Black (freshly burnt area), greenish blue	Medium	Irregular	Gentle to steep slopes
2nd year jhum	Light blue-green, blue tinge	Medium	Irregular	Gentle to steep slopes
3rd year jhum	Light grey with bright red	Medium	Irregular	Gentle to steep slopes
4th year jhum	Light grey with bright red	Medium	Irregular	Gentle to steep slopes
Abandoned jhum	Dull red and/or light red	Medium	Irregular	Gentle to steep slopes

A typical shifting cultivation landscape in FCC where the jhum patches are dispersed within forest vegetation can be seen in Figure 4.1.

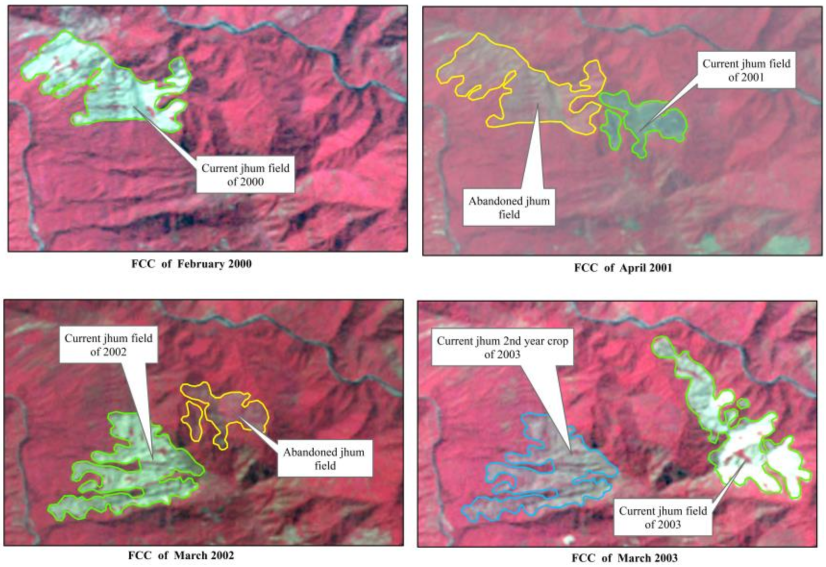


Figure 4.1: Illustration of different shifting cultivation stage as in FCC from 2000 to 2003

To assess the accuracy of the spatial maps, field visit conducted during December 2016/2017/2018 were used to validate the accuracy of the interpretation for the subsequent year, which is jhum fields of 2017/2018/2019.

4.2.4 Determining the cropping and fallow period

Efforts were made to extract the different stages of shifting cultivation with high accuracy polygon-based classification (Inoue et al., 2007, 2008). Digitization of cropped and abandoned jhum land of each year's Landsat image was carried out from the FCC for the study period (1999 to 2017/2018/2019) at 1:50,000 scale. The vector layers of polygon generated for individual satellite image from 1999 to 2017/2018/2019 were then subjected to GIS analysis to obtain details about the cropping and fallow period.

4.2.5 Spatial distribution of jhum patch size

The distribution of the number of area polygons of current jhum from 1999 to 2017/2018/2019 was enumerated to determine the prevalent jhum size in Ukhrul and Chandel districts of Manipur, Champhai and Aizawl districts of Mizoram, Mon and Wokha districts of Nagaland. The land holding size was classified according to guidelines for Agricultural Census, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India.

4.2.6 Analysis of jhum plots with topographical parameters

The elevation, slope and aspect map of the study areas were generated from the ASTER Digital Elevation Model (DEM). The elevation and slope map obtained was categorised into 5 classes while aspect map was categorised into 8 classes. The classified vectorised elevation, aspect and slope maps were again overlaid with the current jhum layers for each year and area statistics for each layer under different slope and aspect categories were generated for further analysis.

4.2.7 Identification of crop-fallow rotation cycle/jhum cycle

The yearly jhum layers (current jhum polygons) of the study period were intersected using overlay tool in ArcGIS 10.2.2 to identify the jhum cycle. The attributes were queried to select polygons which overlapped over a period of time and were categorised in regard to the difference in years between the two periods. The overlapping however may not be for the entire polygon, but a part of the polygon. For instance, current jhum area that overlapped during 2000 and 2007, 2001 and 2008, 2002 and 2009, 2010 and 2017, ...etc would be represented as 7 year jhum cycle area. In this manner, area under different jhum cycle was determined based on the year gap between the two overlapped years.

The detailed methodology adopted for mapping of jhum lands and identification of jhum cycle is shown in Figure 4.2.

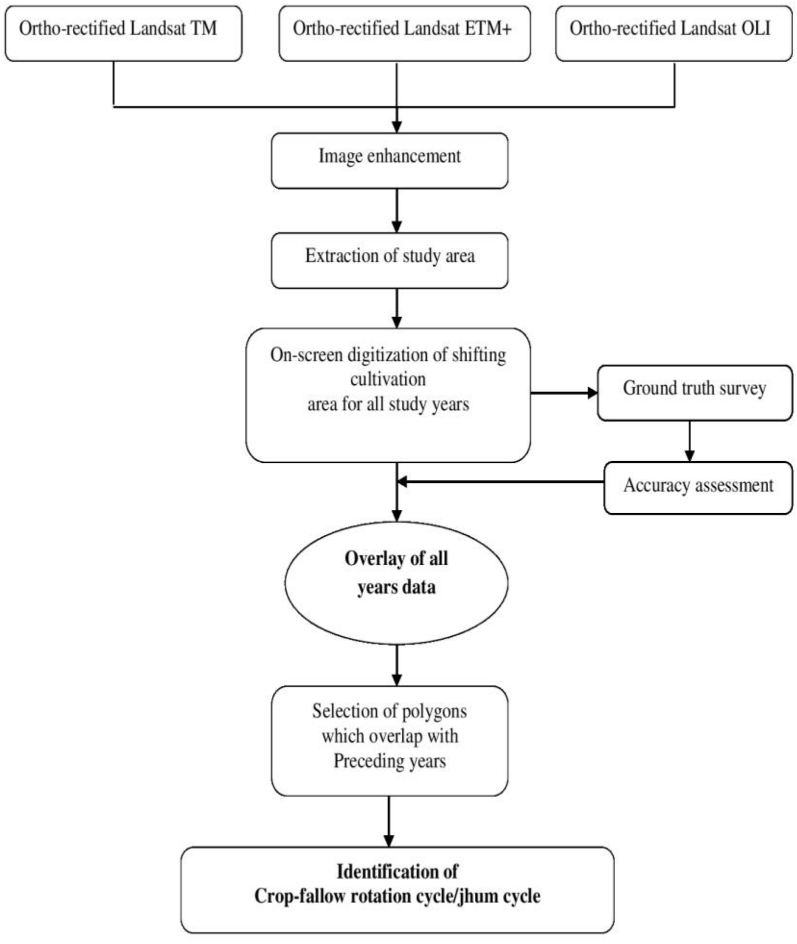


Figure 4.2: Detailed methodology for delineation and identification of crop-fallow cycle/jhum cycle

4.2.8 Population change and its effect on shifting cultivation

Census data of all the six (6) districts was obtained for the study period from the District Census Report given by the Ministry of Home Affairs, Government of India. The decadal population change (2001–2011) of the study area was organised according to the R. D blocks within the districts. The vector layer of blocks was then intersected over the yearly jhum layer (current jhum polygons) of 2001 and 2011 to understand the effect of population change on the shifting cultivation practice.

4.3 Statistical analysis

One-way Analysis of Variance (ANOVA) and linear regression was performed using SPSS version 20.0 to determine the relation between topographical parameters and spatial distribution of jhum patches. Regression analysis was also incorporated to understand the impact of decadal population change on the total jhum area.

4.4 Results

4.4.1 Characteristics of jhum

Land cover change caused by jhum in the study area was traced from 1999 to 2017/2018/2019. The spatial distributions of current jhum patches during the study period are shown in Figure 4.3, 4.4, 4.5, 4.6, 4.7 and 4.8.

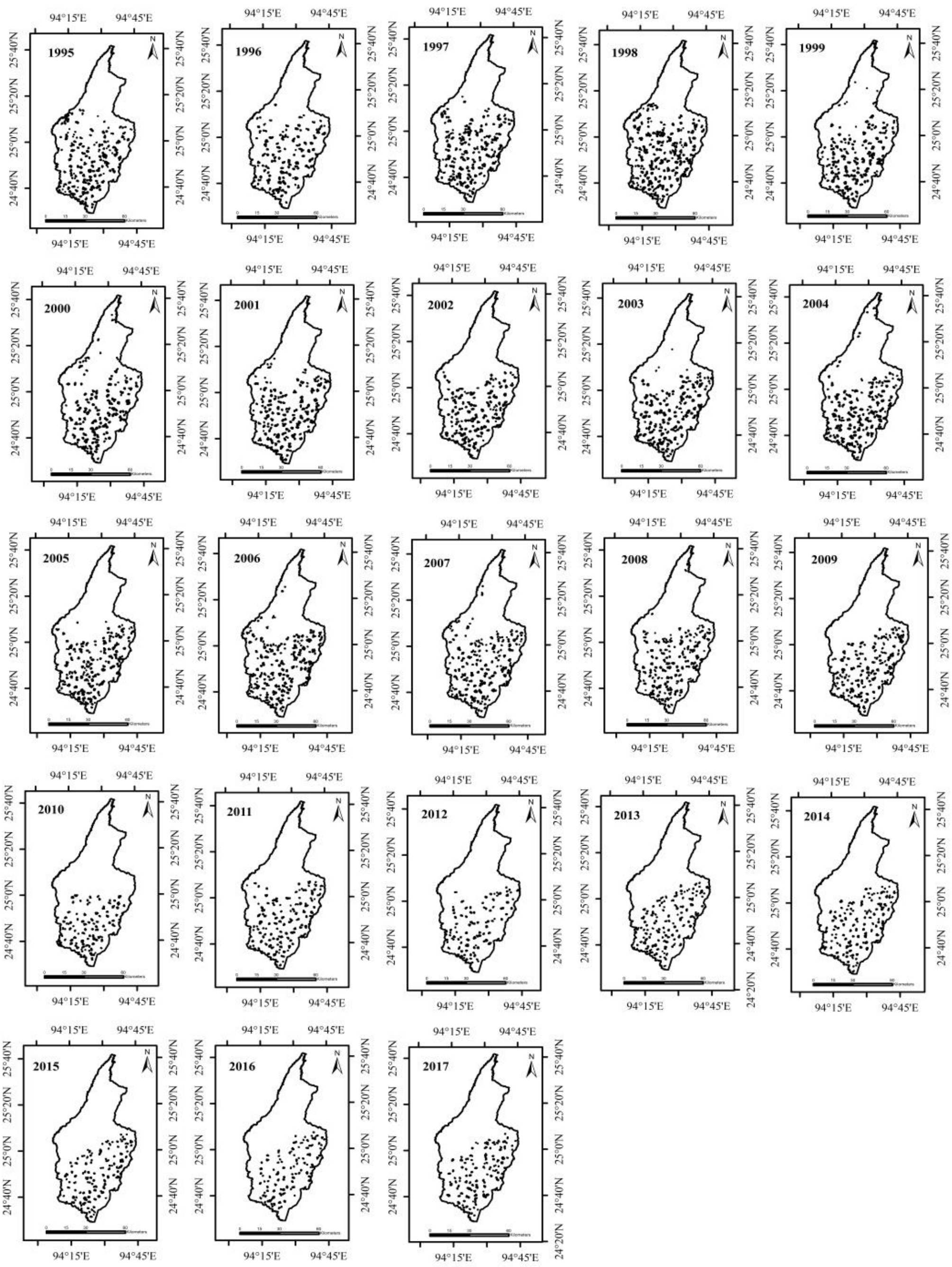


Figure 4.3: Extent of current jhum in Ukhrul during the study period (1995 – 2017)

Figure 4.4: Extent of current jhum in Chandel during the study period (1995 – 2017)

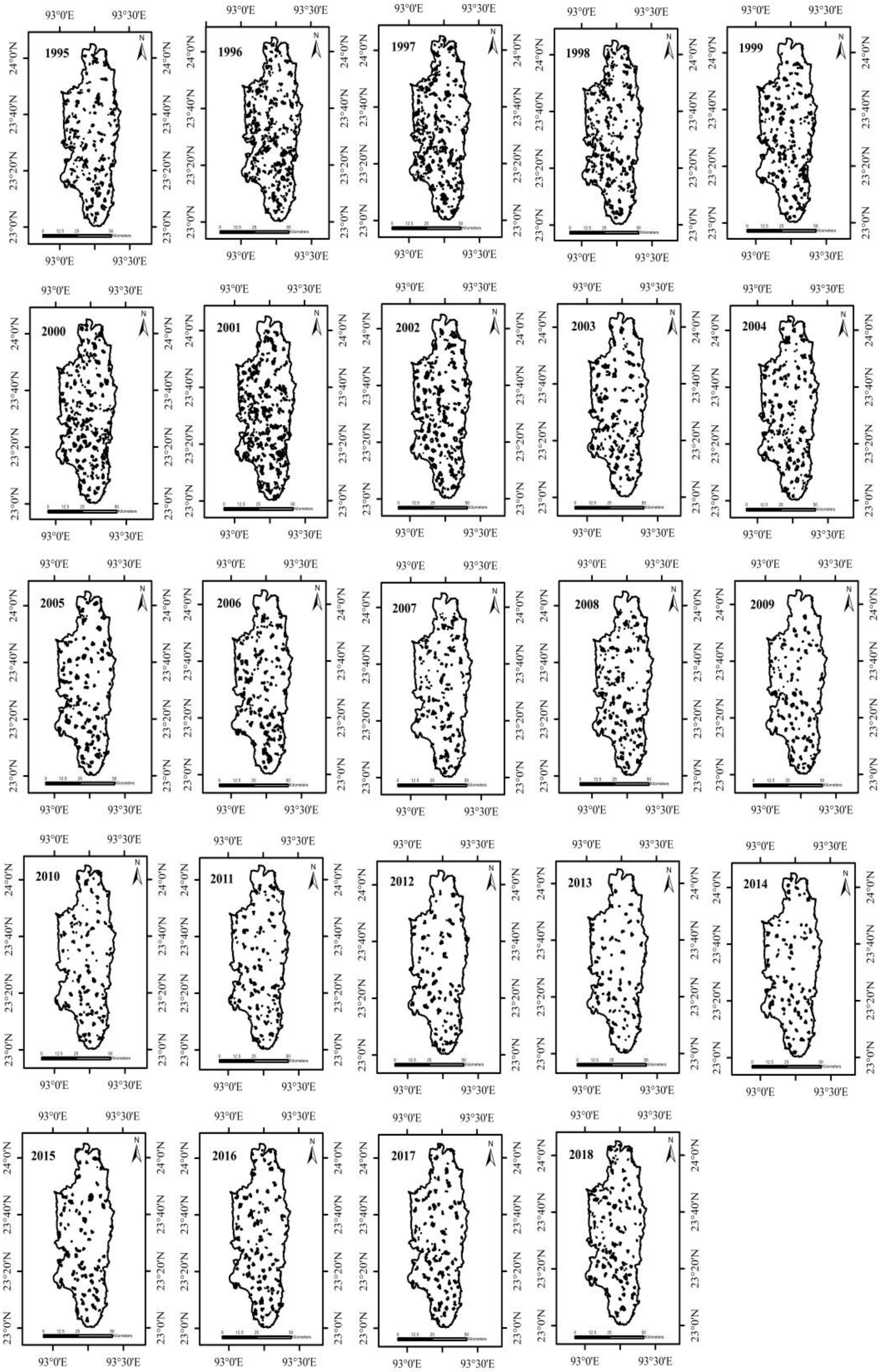


Figure 4.5: Extent of current jhum in Champhai during the study period (1995 – 2018)

Figure 4.6: Extent of current jhum in Aizawl during the study period (1995 – 2018)

Figure 4.7: Extent of current jhum in Mon during the study period (1995 – 2019)

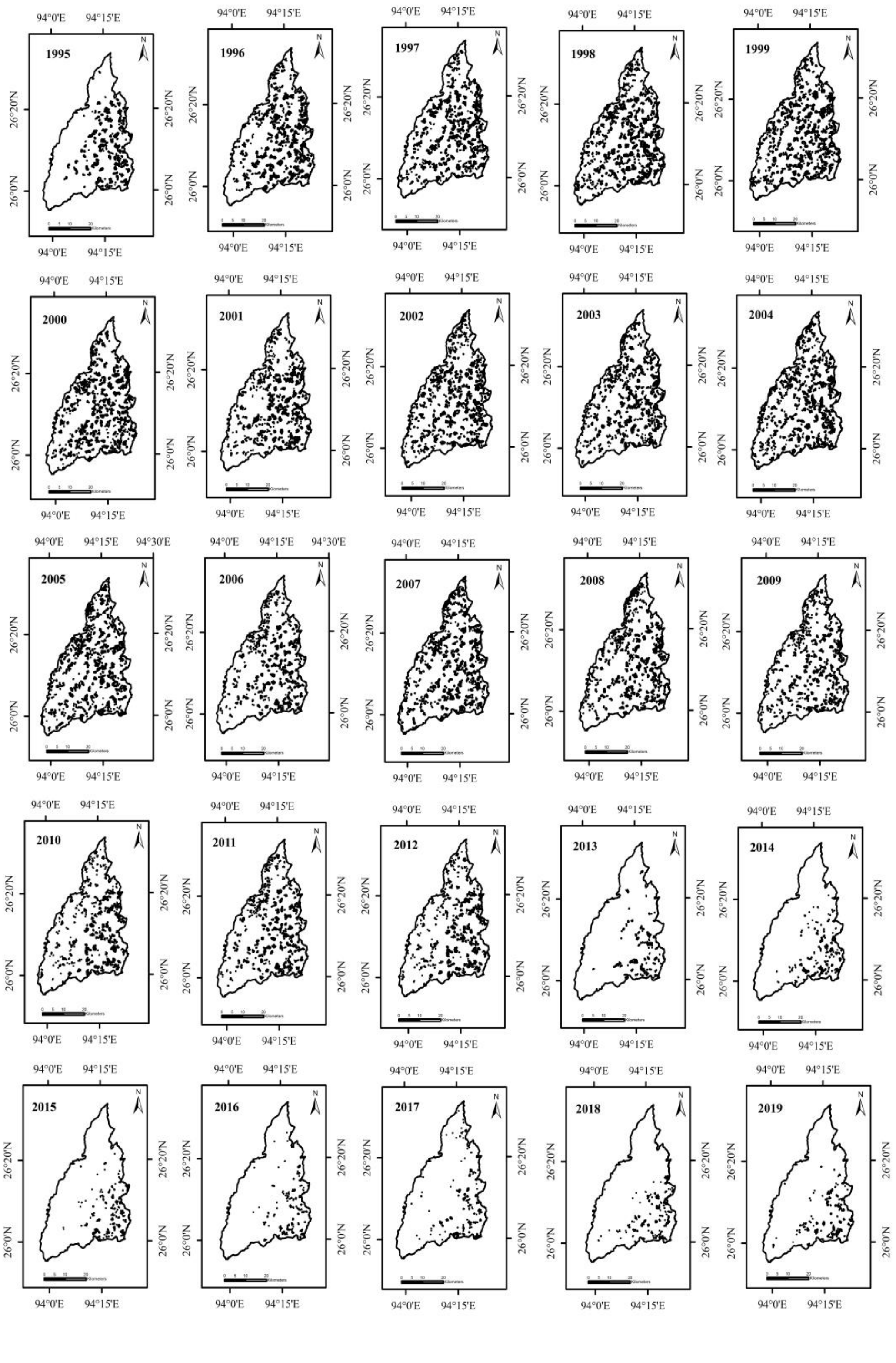


Figure 4.8: Extent of current jhum in Wokha during the study period (1995 – 2019)

The forest area lost due to shifting cultivation in Ukhrul, Chandel, Champhai, Aizawl, Mon and Wokha during the study period are represented in Table 4.3, 4.4 and 4.5.

Table 4.3: Area covered by jhum during the study period in Manipur

Year	**Ukhrul**			**Chandel**		
	Area covered (in Km²)			Area covered (in Km²)		
	Current	2nd year	Abandoned	Current	2nd year	Abandoned
1995	70.70	13.11	0	45.41	11.83	0
1996	44.27	3.25	80.56	36.03	6.74	50.55
1997	57.57	3.83	43.70	43.26	6.24	36.57
1998	73.89	6.90	54.50	52.74	5.71	43.68
1999	83.22	44.35	69.21	71.28	35.79	55.79
2000	71.75	61.08	67.96	39.28	25.72	84.64
2001	86.05	55.63	78.02	76.57	14.16	50.8
2002	69.35	45.06	96.63	55.28	25.01	65.67
2003	78.38	44.51	69.90	65.98	17.70	62.65
2004	73.85	40.04	82.70	65.41	24.29	60.07
2005	69.06	44.91	68.99	54.64	15.03	74.81
2006	62.60	21.66	92.07	62.73	18.98	50.69
2007	57.56	23.48	60.75	43.40	21.15	60.54
2008	53.77	18.84	62.20	38.41	14.54	50.04
2009	55.47	15.18	59.14	39.85	17.74	35.25
2010	40.80	13.75	56.91	36.21	23.19	34.34
2011	43.62	13.32	41.23	16.85	16.15	43.24
2012	37.11	11.6	45.94	45.65	9.24	23.81
2013	38.82	11.22	37.48	33.11	18.08	36.81
2014	39.84	15.30	34.75	35.15	18.61	32.58
2015	36.78	13.10	41.96	27.73	15.08	38.67
2016	26.79	12.46	37.42	21.95	12.25	30.56
2017	22.55	10.27	28.84	14.69	11.03	23.16

Table 4.4: Area covered by jhum during the study period in Mizoram

Year	**Champhai**			**Aizawl**		
	Area covered (in Km²)			Area covered (in Km²)		
	Current	2nd year	Abandoned	Current	2nd year	Abandoned
1995	60.31	4.69	0	76.54	70.51	0
1996	87.35	2.54	62.1	80.45	9.11	137.95
1997	113.09	5.83	84.06	112.28	21.25	68.3
1998	111.14	6.04	113.3	135.72	7.61	125.95
1999	135.54	32.26	82.28	118.15	15.36	129.24
2000	146.54	15.66	152.66	121.3	5.07	128.44
2001	226.49	10.87	168.84	142.03	4.77	121.53
2002	199.17	8.49	230.97	141.37	5.83	141.00
2003	117.94	7.35	208.58	114.73	11.59	135.61
2004	122.67	13.48	111.89	94.87	5.44	121.03
2005	128.05	4.97	131.22	109.07	4.49	95.82
2006	122.59	6.53	126.49	103.9	6.83	106.73
2007	74.23	5.84	123.28	67.39	5.26	105.42
2008	93.29	4.17	75.90	67.54	3.23	69.42
2009	75.45	9.33	88.26	52.01	8.14	64.18

2010	60.99	8.35	77.44	40.54	3.41	56.74
2011	77.85	3.69	65.65	37.04	1.17	42.72
2012	77.04	4.62	76.99	31.99	1.57	36.63
2013	64.97	9.36	72.30	40.65	2.28	31.28
2014	66.63	10.7	63.98	44.19	4.79	38.14
2015	107.53	5.05	72.33	46.41	2.50	46.59
2016	98.29	7.41	105.47	55.51	20.44	46.47
2017	88.12	3.93	101.52	53.92	1.38	56.58
2018	85.72	1.8	90.25	48.06	0.86	54.44

Table 4.5: Area covered by jhum during the study period in Nagaland

Year	**Mon**					**Wokha**				
	Area covered (in Km²)					Area covered (in Km²)				
	Current	2nd year	3rd year	4th year	Abandoned	Current	2nd year	3rd year	4th year	Abandoned
1995	103.09	66.17	0	0	0	39.22	8.52	0	0	0
1996	118.66	69.05	9.21	0	91.00	64.17	6.77	0.80	0	40.17
1997	122.62	82.79	21.00	3.19	89.99	63.04	7.81	0.53	0.09	63.31
1998	117.67	70.41	14.76	0.99	143.44	71.02	7.11	0.99	0.04	63.32
1999	113.78	76.83	15.58	2.06	109.74	82.64	12.11	0.45	0	66.61
2000	102.82	68.35	7.25	2.00	130.64	66.97	9.73	0.53	0	84.93
2001	130.85	68.21	8.98	0.97	102.23	59.46	7.09	0.48	0	69.66
2002	118.38	74.75	7.55	1.17	125.54	68.38	8.46	0.34	0	58.24
2003	113.91	60.96	10.06	1.35	129.49	56.64	5.48	0.11	0	71.58
2004	121.13	70.62	7.39	0.63	107.64	59.30	5.17	0.22	0	56.84
2005	86.20	62.81	3.76	0.24	133.17	56.72	4.27	0.10	0	60.32
2006	109.93	56.00	5.94	0.56	90.51	40.28	5.55	0.17	0	55.38
2007	119.88	67.6	6.51	0.47	97.86	53.62	3.59	0.10	0	42.31
2008	119.79	59.73	6.44	0.36	126.73	46.67	4.97	0.23	0	52.12
2009	111.95	66.71	6.88	0.56	112.20	37.59	4.65	0.38	0	46.84
2010	102.15	60.90	8.78	0.64	115.83	29.39	4.69	0.37	0	37.56
2011	95.95	53.46	7.01	0.34	111.66	43.75	1.95	0	0	32.50
2012	87.03	37.93	3.09	0.07	115.73	30.94	1.23	0	0	44.46
2013	95.45	37.8	1.69	0.10	88.66	24.92	3.82	0	0	28.35
2014	95.45	29.94	1.58	0	103.52	25.74	2.55	0	0	26.19
2015	64.11	35.17	3.32	0	71.17	25.08	4.90	0	0	23.39
2016	76.13	19.93	3.05	0	79.60	23.41	3.84	0	0	26.14
2017	75.00	23.74	0.90	0	74.51	19.17	1.49	0	0	25.76
2018	53.37	24.19	0.67	0	74.99	21.00	2.00	0.02	0	18.64
2019	65.07	17.13	1.05	0	60.06	20.89	2.76	0	0	20.26

All districts showed a decreasing trend in area under current jhum, 2nd year jhum which is the use of same area for cultivation in the following and so forth. An average area of 56.25 Km², 44.42 Km², 105.87 Km², 80.65 Km², 100.81 Km² and 45.20 Km² has been annually slashed for jhum cultivation in Ukhrul, Chandel, Champhai, Aizawl, Mon and Wokha districts respectively. The relative areas (%) of the duration of consecutive cropping period during the study period are shown in Figure 4.9: 4.10 and 4.11.

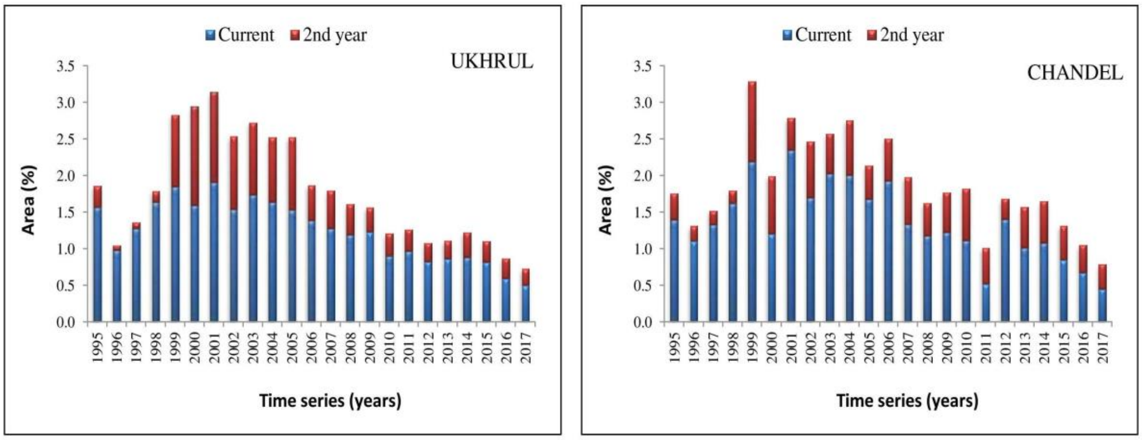


Figure 4.9: Percentage area for consecutive cropping period in Manipur

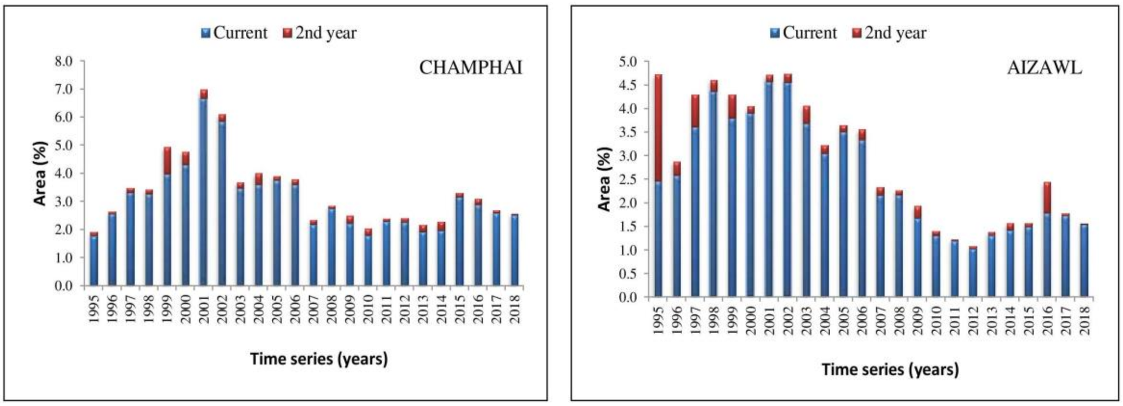


Figure 4.10: Percentage area for consecutive cropping period in Mizoram

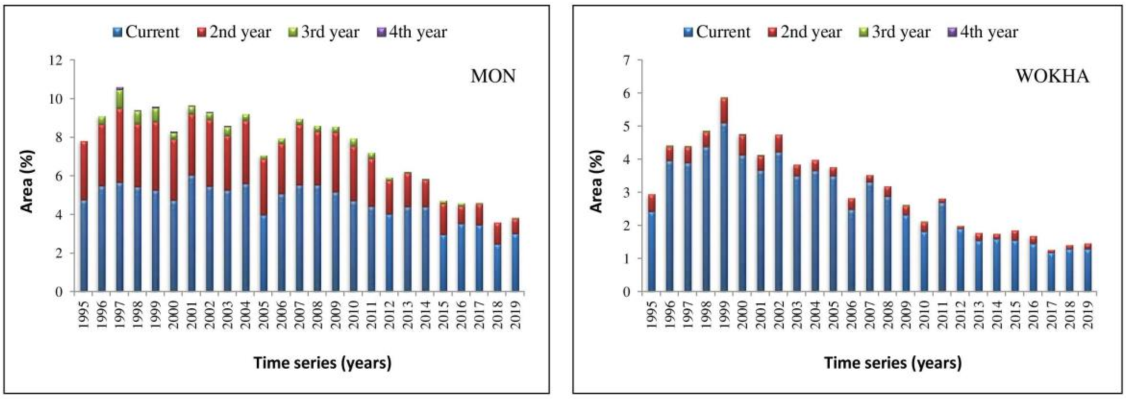


Figure 4.11: Percentage area for consecutive cropping period in Nagaland

It was observed that from the 41.10 % of area under current jhum in Ukhrul 17.25 % continued with 2nd year cropping, while in Chandel 15.68% of jhumias continued with 2nd year cropping out of 41.69% of area under current jhum. In Champhai an average of 48.68% of area under shifting cultivation was newly slashed for current jhum and only 3.70% continued with 2nd year cropping. On the other hand, an average of 46.99% of area under shifting cultivation was newly slashed for current jhum in Aizawl and only 5.41% continued with 2nd year cropping. Nagaland witnessed the cropping period upto 4th year for small fractions of jhumias. In Mon, 38.50% of area under shifting cultivation was newly slashed patches for current jhum, out of which 21% jhumias continued with 2nd year cropping, 2.5% continued with 3rd year cropping and 0.3% with 4th year cropping. Furthermore, from the 47.45% of area under current jhum in Wokha about 5.48 % continued with 2nd year cropping, and 0.24% and 0.01% with 3rd and 4th year cropping respectively.

Based on the ground truth data, the different phases of jhum of each year from 1999 to 2017/2018/2019 were mapped with an interpretation accuracy of 82.48%.

4.4.2 Patch size distribution of jhum plots

The current jhum polygons of different sizes in the study areas are presented in the form of box plot (Figure 4.12, 4.13, 4.14).

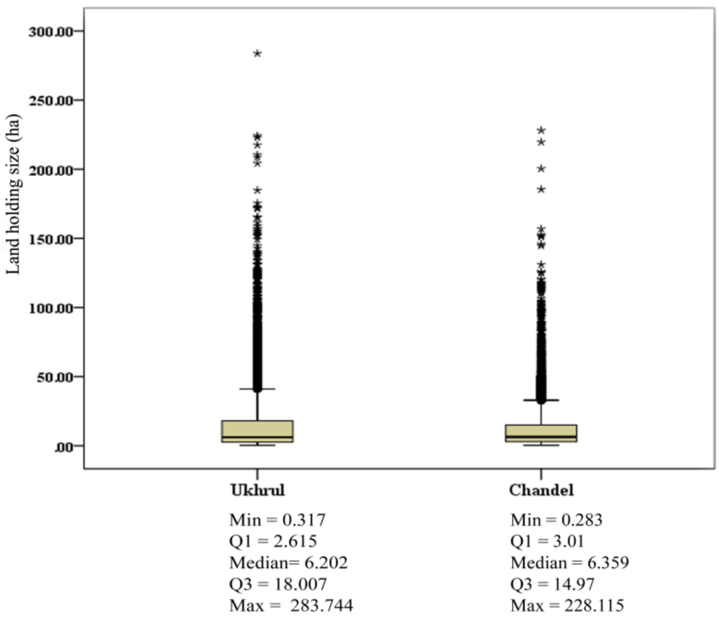


Figure 4.12: Box plot for different sizes of jhum patch in Ukhrul and Chandel

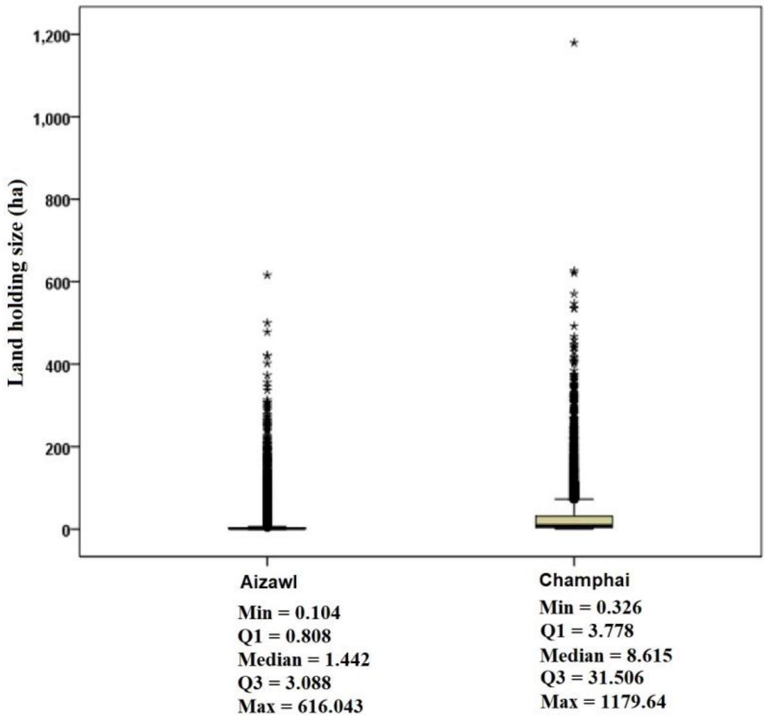


Figure 4.13: Box plot for different sizes of jhum patch in Champhai and Aizawl

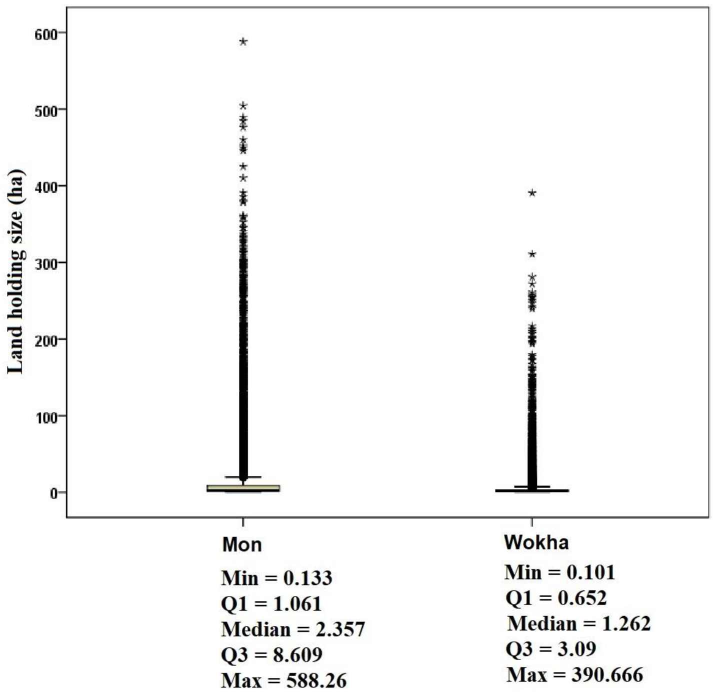


Figure 4.14: Box plot for different sizes of jhum patch in Mon and Wokha

It was found that 75% (Q3) of the patch size varied from 0.32 ha to 18.01 ha in Ukhrul, 0.28 to 14.97 ha in Chandel, 0.33 to 31.51 in Champhai, 0.10 to 3.09 in Aizawl, 0.13 to 8.61 in Mon and 0.10 to 3.09 in Wokha. The number of polygons (current jhum plots) over the study period was then categorised according to the land holding groups (Table 4.6, 4.7, 4.8).

Table 4.6: Land holding size classification in Manipur

Group	Code	Classes (in ha.)	**Ukhrul**	**Chandel**
			No. of polygons ± SD	No. of polygons ± SD
Marginal	M1	Below 0.5 ha	14 ± 0.07	4 ± 0.12
	M2	0.5 - 1.0 ha	237 ± 0.13	112 ± 0.12
Small	S	1.0 - 2.0 ha	907 ± 0.29	748 ± 0.28
Semi - medium	Sm1	2.0 - 3.0 ha	725 ± 0.30	787 ± 0.29
	Sm2	3.0 - 4.0 ha	521 ± 0.29	615 ± 0.29
Medium	Md1	4.0 - 5.0 ha	383 ± 0.28	470 ± 0.29
	Md2	5.0 - 7.5 ha	709 ± 0.70	865 ± 0.73
	Md3	7.5 - 10.0 ha	446 ± 0.72	565 ± 0.73
Large	L1	10.0 - 20.0 ha	937 ± 2.75	1149 ± 2.86
	L2	20.0 ha and above	1480 ± 31.57	1167 ± 25.06

Table 4.7: Land holding size classification in Mizoram

Group	Code	Classes (in ha.)	**Champhai**	**Aizawl**
			No. of polygons ± SD	No. of polygons ± SD
Marginal	M1	Below 0.5 ha	12	2326 ± 0.08
	M2	0.5 - 1.0 ha	52 ± 0.12	6613 ± 0.14
Small	S	1.0 - 2.0 ha	430 ± 0.28	7397 ± 0.28
Semi - medium	Sm1	2.0 - 3.0 ha	563 ± 0.29	3089 ± 0.29
	Sm2	3.0 - 4.0 ha	500 ± 0.28	1610 ± 0.29
Medium	Md1	4.0 - 5.0 ha	428 ± 0.29	997 ± 0.29
	Md2	5.0 - 7.5 ha	669 ± 0.70	1299 ± 0.70
	Md3	7.5 - 10.0 ha	466 ± 0.71	658 ± 0.70
Large	L1	10.0 - 20.0 ha	806 ± 2.90	973 ± 2.75
	L2	20.0 ha and above	1832 ± 85.20	1146 ± 63.29

Table 4.8: Land holding size classification in Nagaland

Group	Code	Classes (in ha.)	**Mon**	**Wokha**
			No. of polygons ± SD	No. of polygons ± SD
Marginal	M1	Below 0.5 ha	530 ± 0.08	2804 ± 0.09
	M2	0.5 - 1.0 ha	1818 ± 0.14	4681 ± 0.14
Small	S	1.0 - 2.0 ha	2269 ± 0.28	4003 ± 0.29
Semi - medium	Sm1	2.0 - 3.0 ha	1102 ± 0.28	1770 ± 0.28
	Sm2	3.0 - 4.0 ha	636 ± 0.28	937 ± 0.28
Medium	Md1	4.0 - 5.0 ha	447 ± 0.29	584 ± 0.29
	Md2	5.0 - 7.5 ha	619 ± 0.71	873 ± 0.72
	Md3	7.5 - 10.0 ha	406 ± 0.74	478 ± 0.72
Large	L1	10.0 - 20.0 ha	728 ± 2.88	790 ± 2.73
	L2	20.0 ha and above	1621 ± 79.65	894 ± 43.64

Owing to the wide range of land holding size in the large group (20 - 284 ha in Ukhrul, 10 - 228 ha in Chandel and 20 - 1180 ha in Champhai) which coincides with 25% of the Q3 above the inter quartile range, the significance of the large group being more prominent is neglected for the following districts. As such, maximum number of jhum size fall into the Small (S) group in Ukhrul and Medium (Md2) group in Chandel and Champhai, and hence the prevalent jhum size is 1 – 2 ha in Ukhrul and 5 – 7.5 ha in Chandel and Champhai. In addition, Wokha is dominated by jhum plots of 0.5 – 1 ha size and Aizawl and Mon with 1 – 2 ha jhum plots.

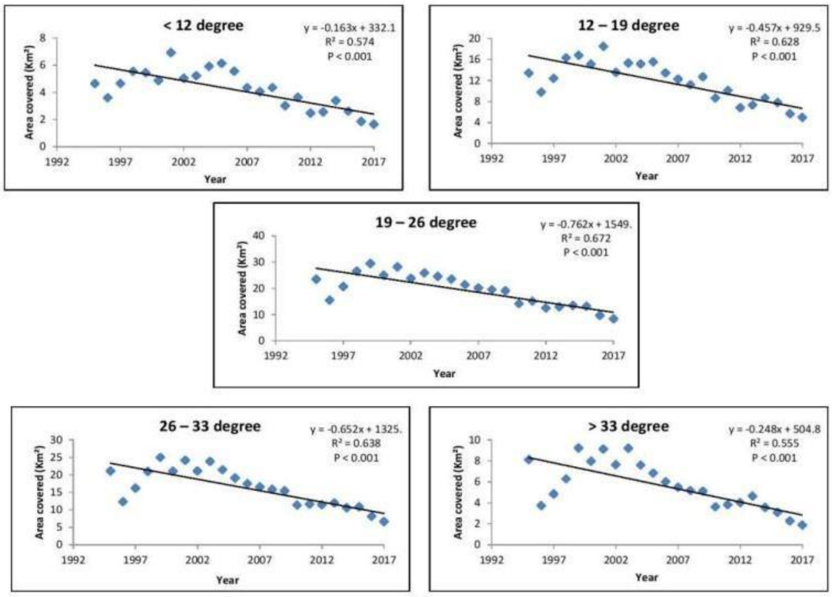
4.4.3 Distribution of jhum plots with respect to topography

The percent area under shifting cultivation in different slope classes of the study area is shown in Figure 4.15, 4.16, 4.17. Over the study period, there has been a significant decrease in jhum area under every slope classes ($P<0.05$) except for Champhai where the changes were not significant in any slope group. Majority of the jhum patches (33.86% and 37.03%) were confined to 19°-26° slope in Ukhrul and 17°-23° slope in Chandel. It was also observed that Champhai and Aizawl had larger part of its jhum area (37.33% and 33.68%) under 18°-26° slope and 11°-19° slope classes. Furthermore, 30.97% and 30.94% of jhum area in Mon and Wokha occurred in 17°-25° slope and 9°-17° slope classes respectively.

Every district displayed a significant decrease in jhum area at different aspect classes ($P \leq 0.001$) other than Champhai in which the changes were not significant at S, SW, W, NW and N aspect (Figure 4.18, 4.19, 4.20). It was also observed that Champhai and Aizawl had most of its jhum area (14.96% and 16.15%) confined to the E aspect while Ukhrul and Wokha had 15.04% and 15.44% of its jhum area under SE aspect. Jhum patches were predominant in the NE and NW aspect of Chandel and Mon respectively.

During the study period, there has been decrease in the jhum area at every elevation class excluding Chandel and Wokha district (Figure 4.21, 4.22, 4.23). Slight increase in the area under jhum at elevation greater than 1165 m and 1335 m a.s.l has been noticed in Wokha and Chandel respectively. Greater area of jhum (30-45%) in Ukhrul, Chandel, Champhai and Mon were confined to elevation ranging from 700 – 1200 m a.s.l. It was also observed that 32.58% of jhum area in Aizawl occurred at an elevation of 597 – 839 m a.s.l while Wokha had 31.72% of its jhum area at an elevation of 350 – 556 m a.s.l.

UKHRUL



CHANDEL

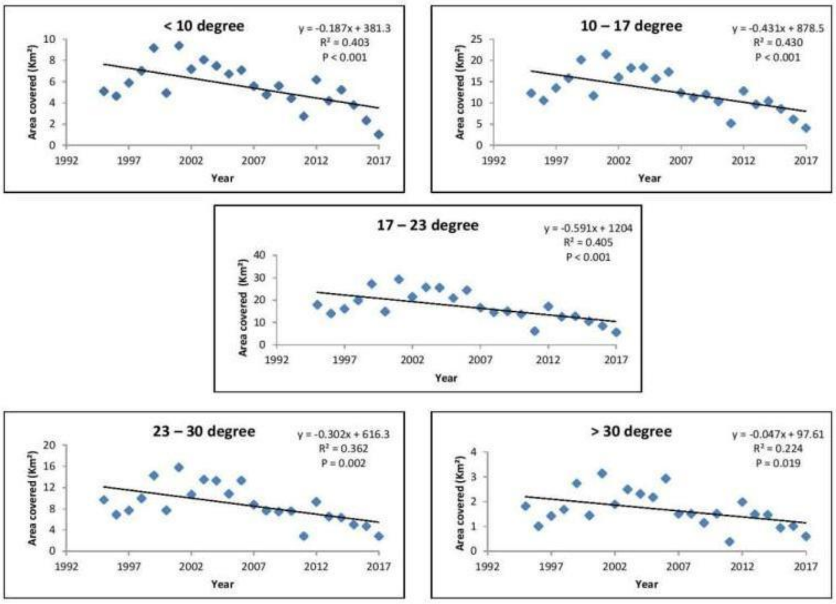
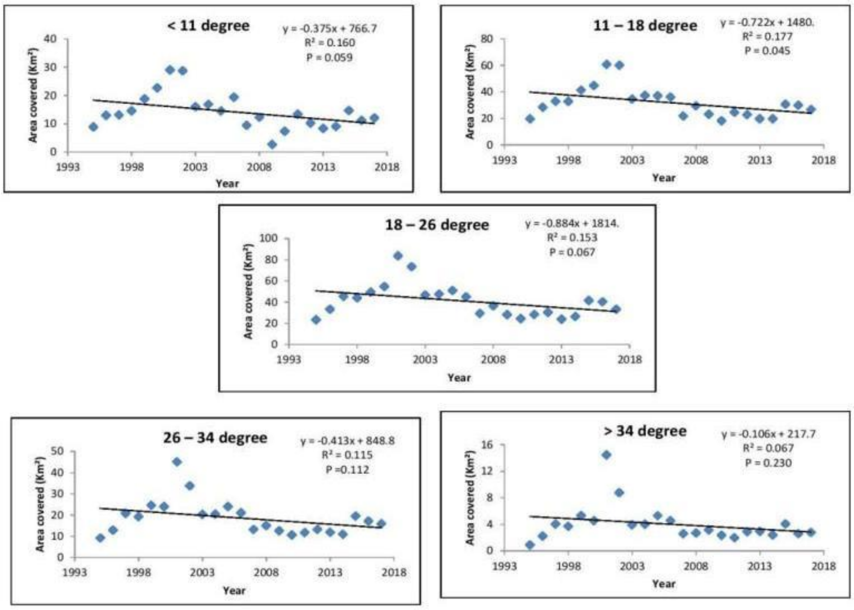


Figure 4.15: Area under shifting cultivation in different slope category in Manipur

CHAMPHAI



AIZAWL

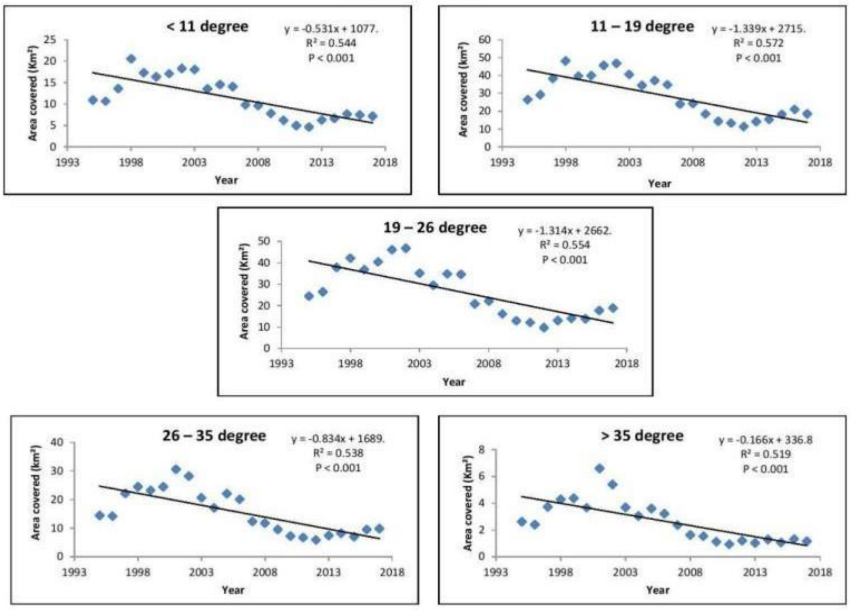
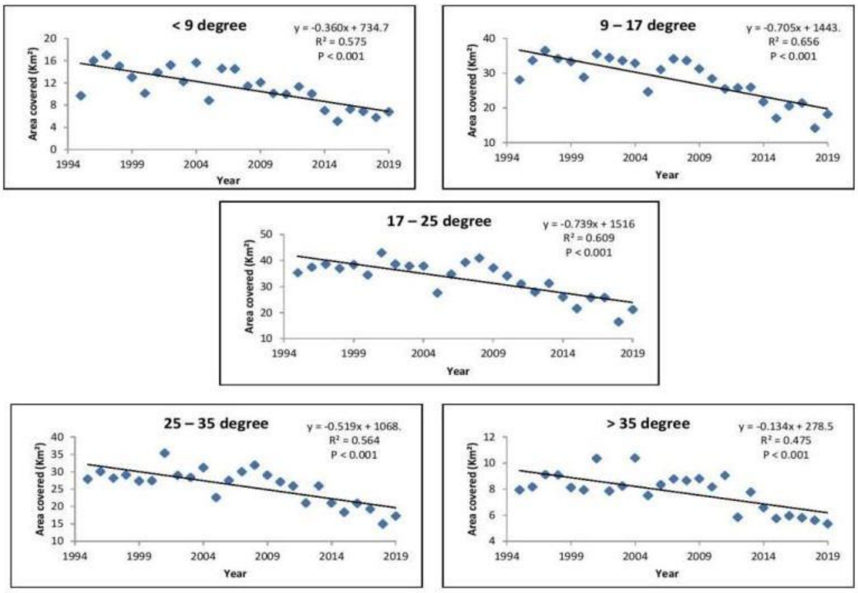


Figure 4.16: Area under shifting cultivation in different slope category in Mizoram

MON



WOKHA

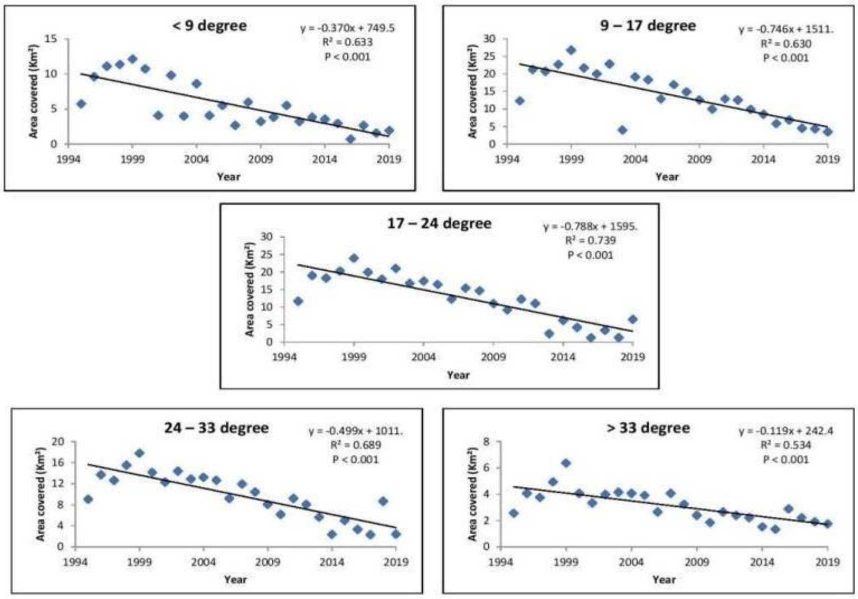


Figure 4.17: Area under shifting cultivation in different slope category in Nagaland

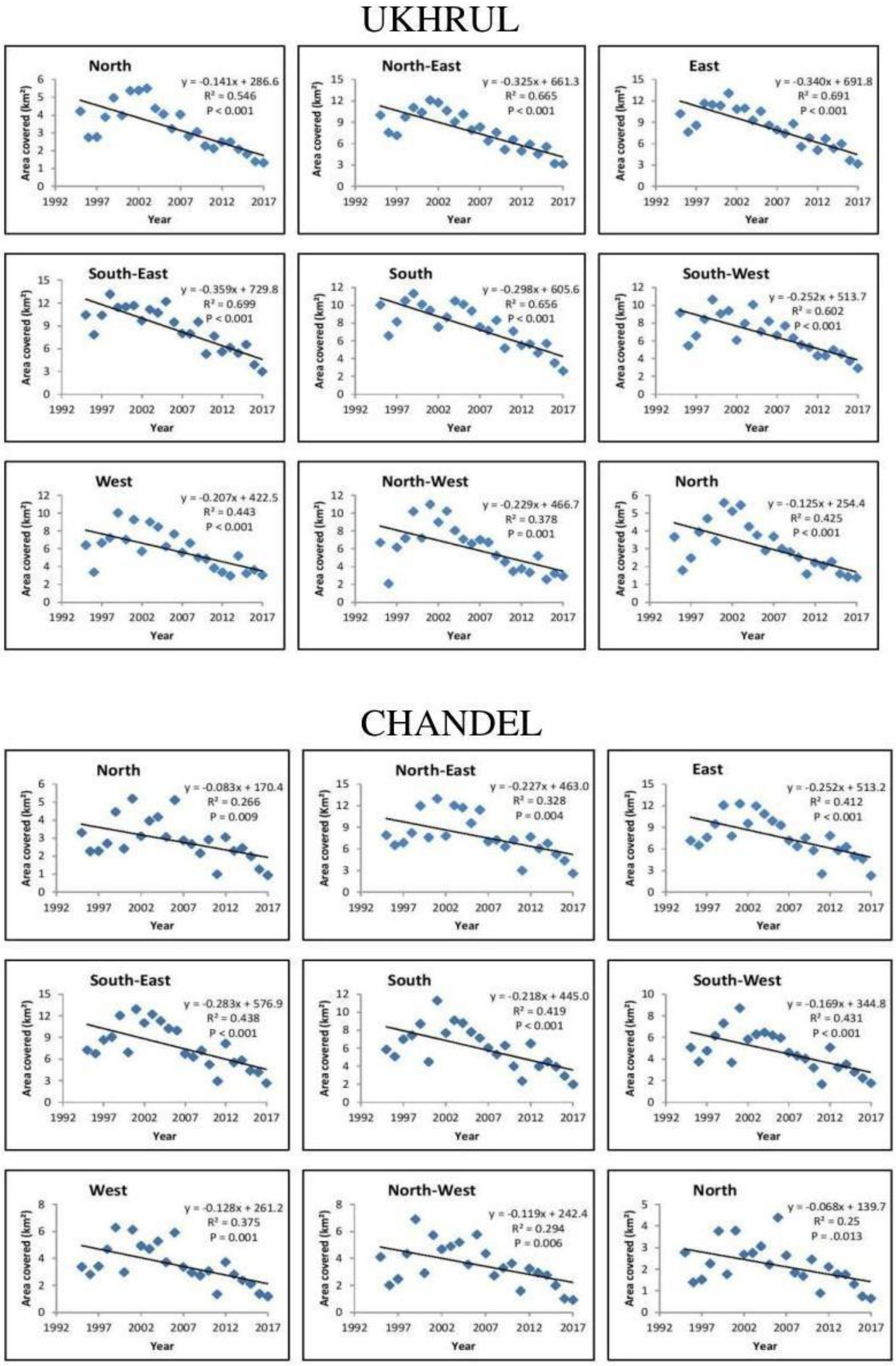


Figure 4.18: Area under shifting cultivation in different aspect category in Manipur

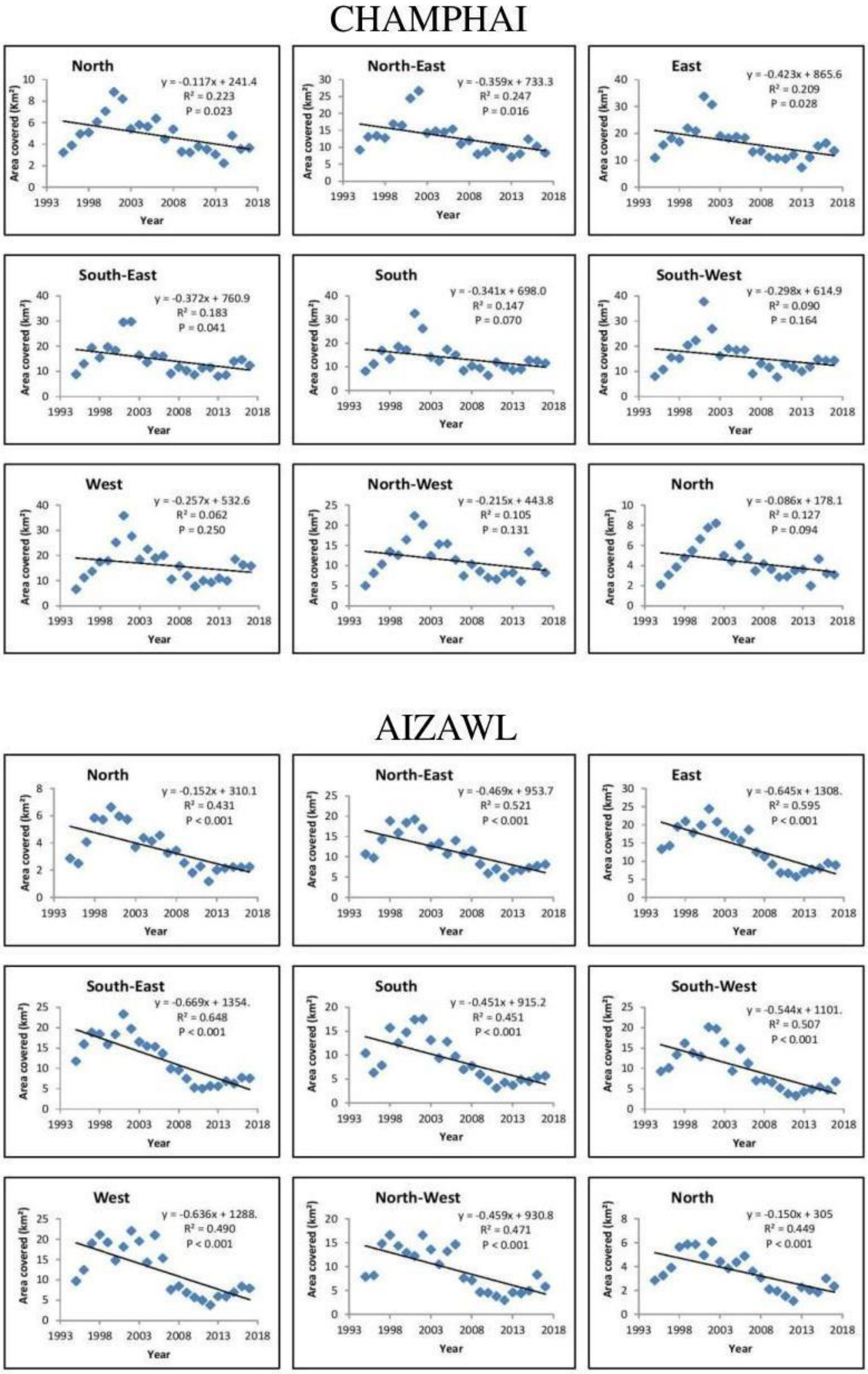
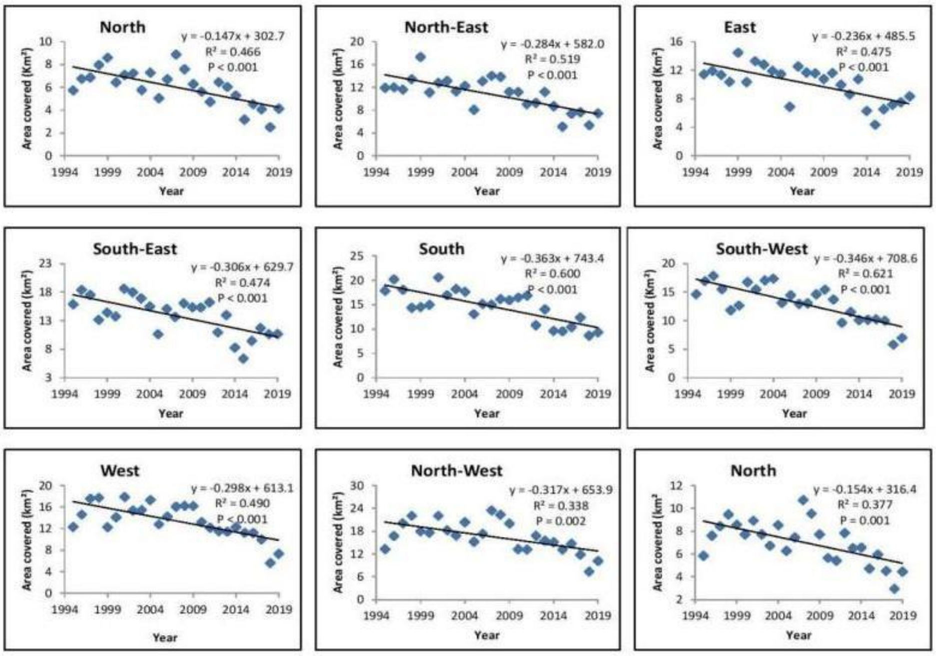


Figure 4.19: Area under shifting cultivation in different aspect category in Mizoram

MON



WOKHA

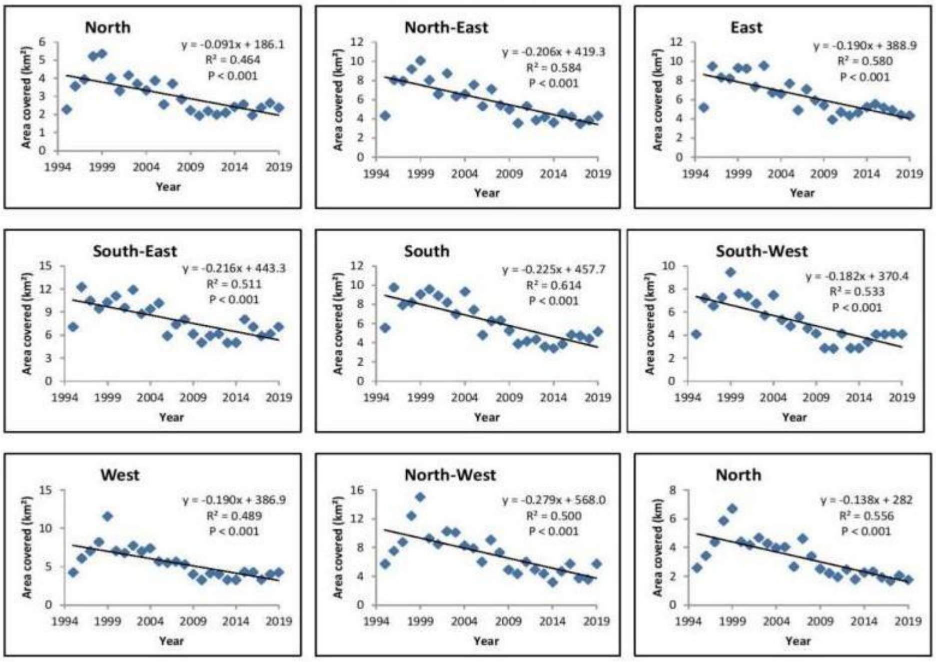


Figure 4.20: Area under shifting cultivation in different aspect category in Nagaland

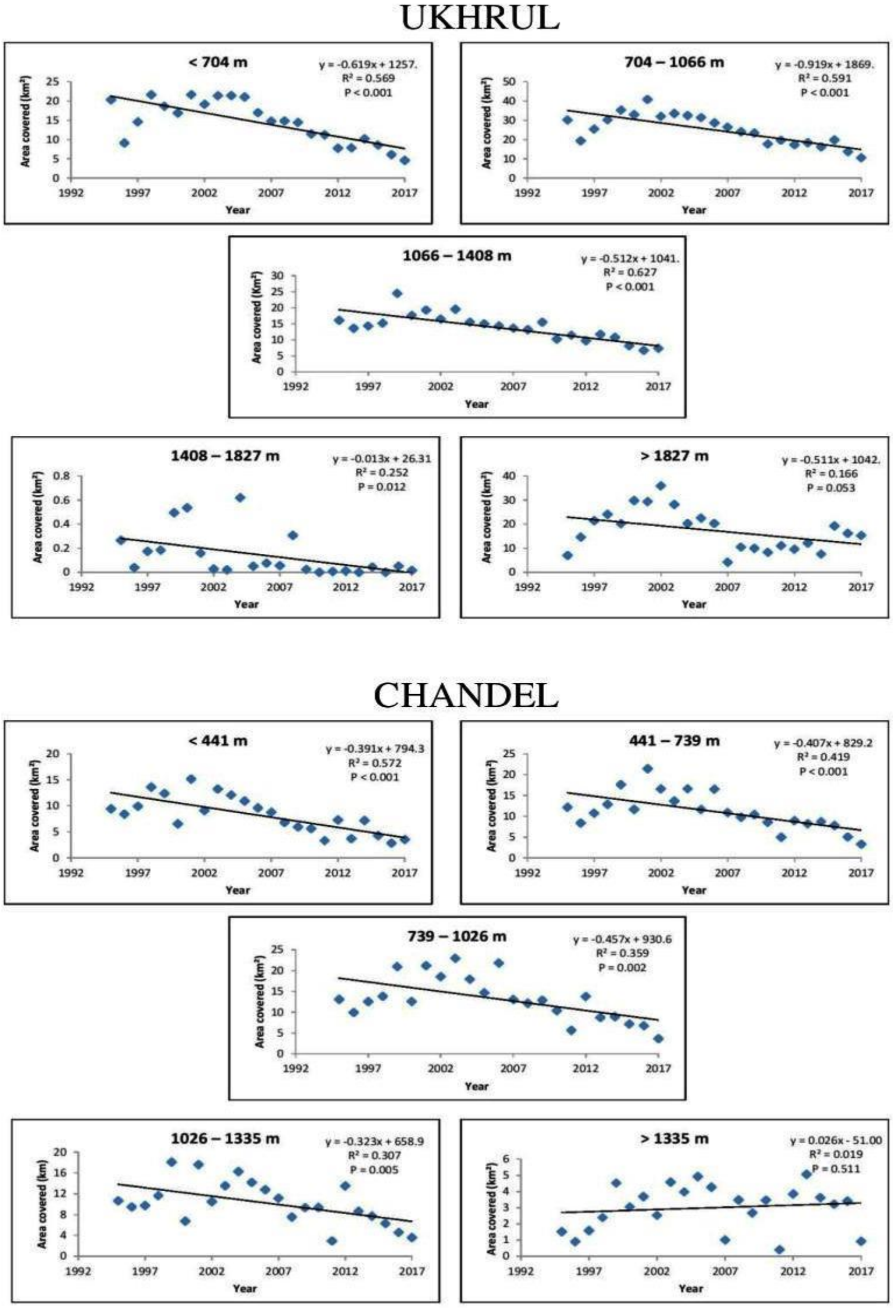


Figure 4.21: Area under shifting cultivation in different elevation category in Manipur

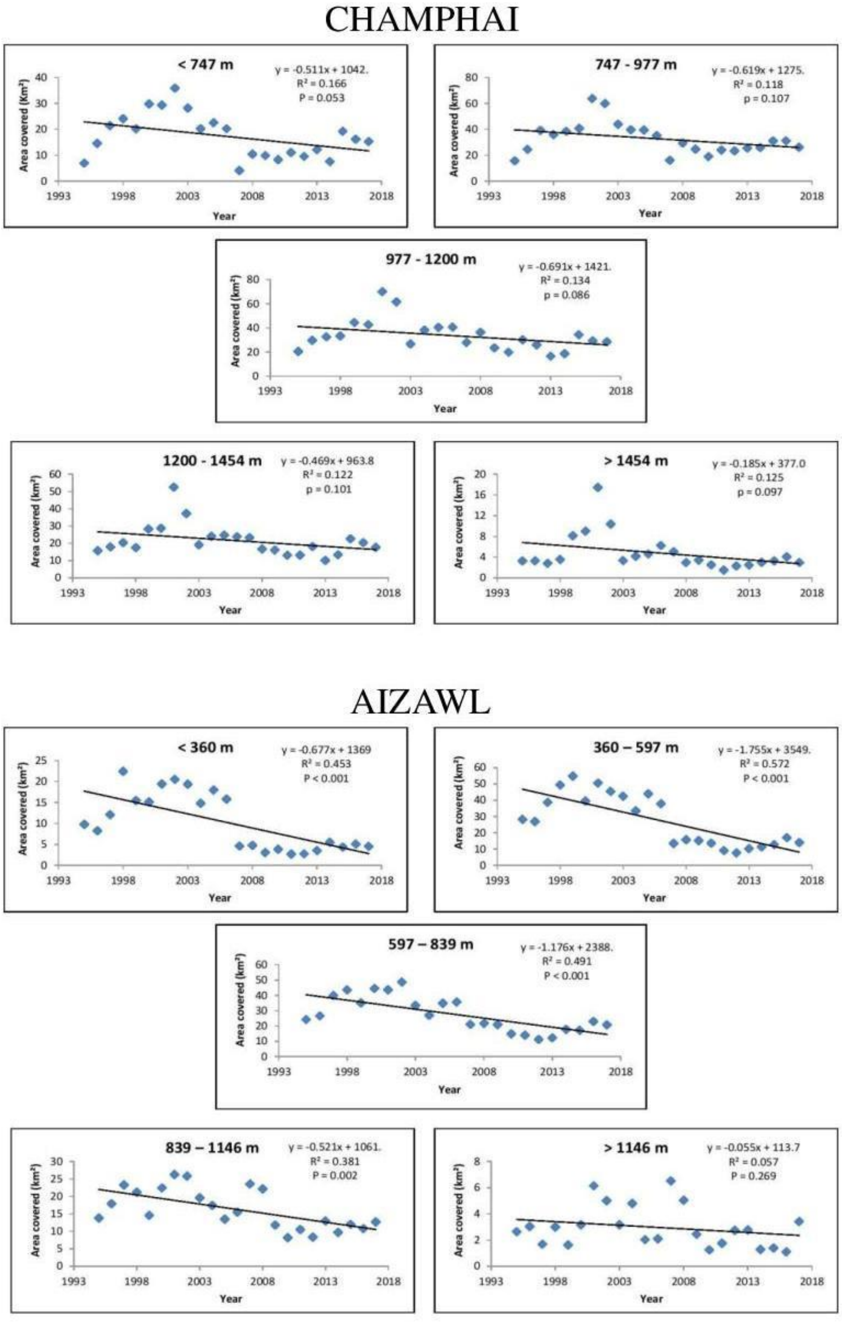
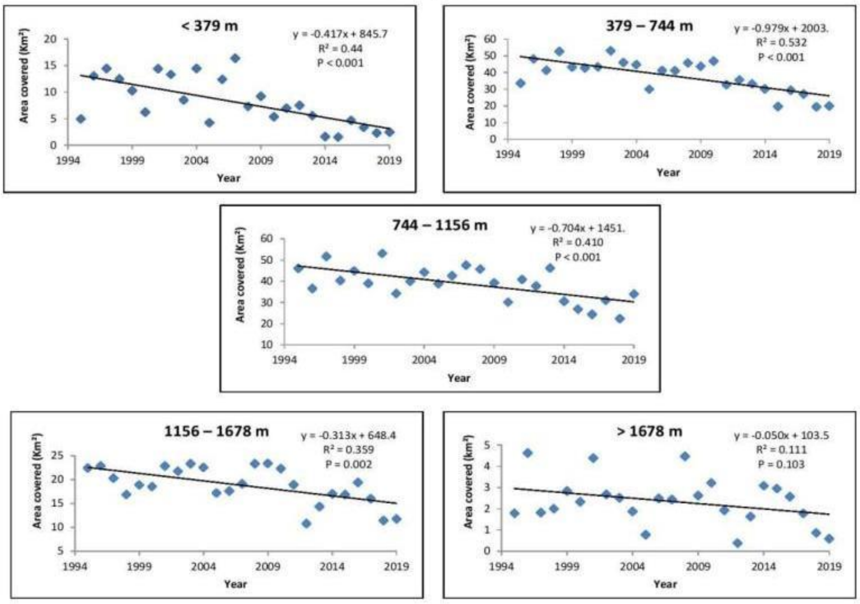


Figure 4.22: Area under shifting cultivation in different elevation category in Mizoram

MON



WOKHA

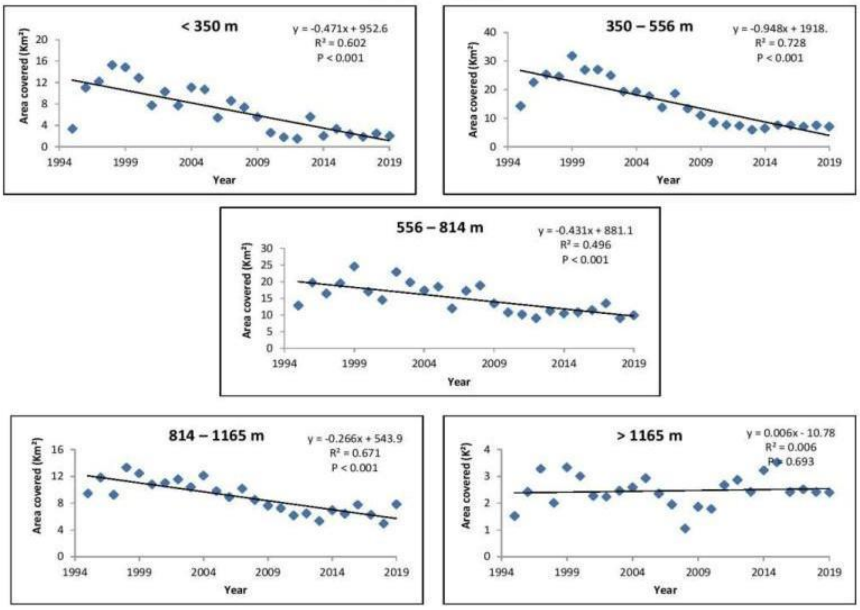


Figure 4.23: Area under shifting cultivation in different elevation category in Nagaland

4.4.4 Prevailing crop-fallow rotation cycle/ jhum cycle

The area under different jhum cycles in Ukhrul and Chandel districts over the study period is shown in Table 4.9. It can be noted that in both the districts, 11 years cycle covers the maximum area followed by 10 years cycle. It was also observed that jhum cycle of 10–14 years were most prevalent in Ukhrul (69.05% of the total area affected by jhum) while jhum cycle of 9–13 years were most prevalent in Chandel (59.32% of the total area affected by jhum). Therefore, with cropping phase of two years, the fallow period of 8–12 years and 7–11 years are most dominant in Ukhrul and Chandel districts of Manipur respectively.

Table 4.9: Area covered by different jhum cycles over the study period (1995-2017) in Manipur

Jhum cycle	Ukhrul			Chandel		
	No. of polygons	Area (Km²)	Percentage	No. of polygons	Area (Km²)	Percentage
2 Years	148	0.61	0.21	70	0.33	0.17
3 Years	689	1.31	0.46	649	1.79	0.89
4 Years	722	2.00	0.70	641	2.56	1.27
5 Years	772	1.87	0.66	683	2.33	1.16
6 Years	654	2.47	0.87	835	4.86	2.42
7 Years	833	4.39	1.54	1168	10.02	4.99
8 Years	974	8.27	2.91	1479	14.06	7.00
9 Years	1251	16.39	5.76	1789	20.14	10.03
10 Years	2534	35.82	12.58	1850	25.41	12.66
11 Years	2270	53.38	18.76	1573	31.65	15.76
12 Years	1418	33.15	11.65	1250	21.19	10.55
13 Years	1529	44.77	15.73	1065	20.73	10.32
14 Years	994	29.41	10.33	853	16.50	8.22
15 Years	661	15.89	5.58	624	11.63	5.79
16 Years	539	14.48	5.09	423	5.27	2.63
17 Years	425	7.81	2.74	326	4.66	2.32
18 Years	279	5.35	1.88	262	2.64	1.31
19 Years	247	3.69	1.30	243	2.56	1.27
20 Years	204	2.45	0.86	169	1.74	0.87
21 Years	38	0.66	0.23	80	0.29	0.15
22 Years	66	0.44	0.15	27	0.43	0.22

The area under different jhum cycles in Champhai and Aizawl districts over the study period is shown in Table 4.10. In Champhai, 10 years cycle covered the maximum area followed by 11 years cycle while in Aizawl 8 years cycle covered the maximum area followed by 9 years cycle. It was also observed that jhum cycle of 9–11 years were most prevalent in Champhai (41.95% of the total area affected by jhum) while jhum cycle of 7–10 years were most prevalent in Aizawl (54.52% of the total area affected by jhum). Therefore, with cropping phase of two years, the fallow period of 7–9 years and 5–8 years are most dominant in Champhai and Aizawl districts of Mizoram respectively.

Table 4.10: Area covered by different jhum cycles over the study period (1995-2018) in Mizoram

Jhum cycle	Champhai			Aizawl		
	No. of polygons	Area (Km^2)	Percentage	No. of polygons	Area (Km^2)	Percentage
2 Years	238	3.44	0.47	353	0.41	0.08
3 Years	1018	5.08	0.69	3170	5.08	1.00
4 Years	1147	6.76	0.92	3449	7.09	1.40
5 Years	1185	7.05	0.96	4231	12.31	2.42
6 Years	1700	11.38	1.55	5851	30.61	6.03
7 Years	2916	30.04	4.10	8607	66.45	13.08
8 Years	4015	60.05	8.19	9790	85.62	16.86
9 Years	4749	90.20	12.31	7750	70.89	13.96
10 Years	4956	118.39	16.16	6581	53.95	10.62
11 Years	4008	98.80	13.48	4988	38.66	7.61
12 Years	2658	71.77	9.79	4085	30.57	6.02
13 Years	1920	70.04	9.56	3169	19.41	3.82
14 Years	1512	49.88	6.81	2886	16.90	3.33
15 Years	1318	32.12	4.38	2700	16.99	3.35
16 Years	1146	23.83	3.25	2554	15.17	2.99
17 Years	1072	18.32	2.50	1951	11.70	2.30
18 Years	896	15.46	2.11	1998	11.53	2.27
19 Years	539	6.07	0.83	1251	6.57	1.29
20 Years	749	8.19	1.12	910	3.85	0.76
21 Years	450	3.80	0.52	582	2.39	0.47
22 Years	212	1.82	0.25	362	1.01	0.20
23 Years	62	0.25	0.03	192	0.80	0.16

The area under different jhum cycles in Mon and Wokha districts over the study period is shown in Table 4.11. In Mon, 7 years cycle covered the maximum area followed by 8 years cycle while in Wokha 8 years cycle covered the maximum area followed by 9 years cycle. It was also observed that jhum cycle of 6–9 years were most prevalent in both the districts, contributing about 67.77% and 64.37% of the total area affected by jhum respectively. Therefore, with cropping phase of two years, the fallow period of 4–7 years is most dominant in Mon and Wokha districts of Nagaland respectively.

Table 4.11: Area covered by different jhum cycles over the study period (1995-2019) in Nagaland

Jhum cycle	Mon			Wokha		
	No. of polygons	Area (Km²)	Percentage	No. of polygons	Area (Km²)	Percentage
2 Years	1264	1.31	0.16	9495	562.55	2.11
3 Years	2019	3.19	0.39	1732	213.14	0.80
4 Years	2070	2.64	0.33	2273	307.44	1.15
5 Years	7095	18.45	2.28	3426	830.20	3.11
6 Years	22951	88.39	10.93	6267	2992.31	11.22
7 Years	39563	212.04	26.22	6736	3657.23	13.72
8 Years	19583	149.71	18.51	7583	6804.40	25.52
9 Years	10717	97.94	12.11	4621	3705.38	13.90
10 Years	9195	73.09	9.04	3151	2036.88	7.64
11 Years	5185	48.09	5.95	2601	1197.09	4.49
12 Years	8735	42.13	5.21	2688	1130.05	4.24
13 Years	2414	9.59	1.19	1877	733.43	2.75
14 Years	8481	29.69	3.67	1295	497.04	1.86
15 Years	2774	7.82	0.97	1469	581.04	2.18
16 Years	3158	12.65	1.56	1607	648.96	2.43
17 Years	994	2.71	0.34	821	296.57	1.11
18 Years	2285	4.81	0.59	504	99.65	0.37
19 Years	548	0.91	0.11	471	108.13	0.41
20 Years	1002	1.24	0.15	312	66.87	0.25
21 Years	1186	1.51	0.19	478	107.68	0.40
22 Years	329	0.35	0.04	234	53.87	0.20
23 Years	139	0.28	0.04	118	23.65	0.09
24 Years	201	0.16	0.02	58	5.13	0.02

4.4.5 Relation between population and spatial variation of jhum patches

The relationship between decadal change in population (%) of all the blocks and the decadal change of jhum area (%) at each land holding class in Manipur was enumerated and represented in the form of a bar graph (Figure 4.24).

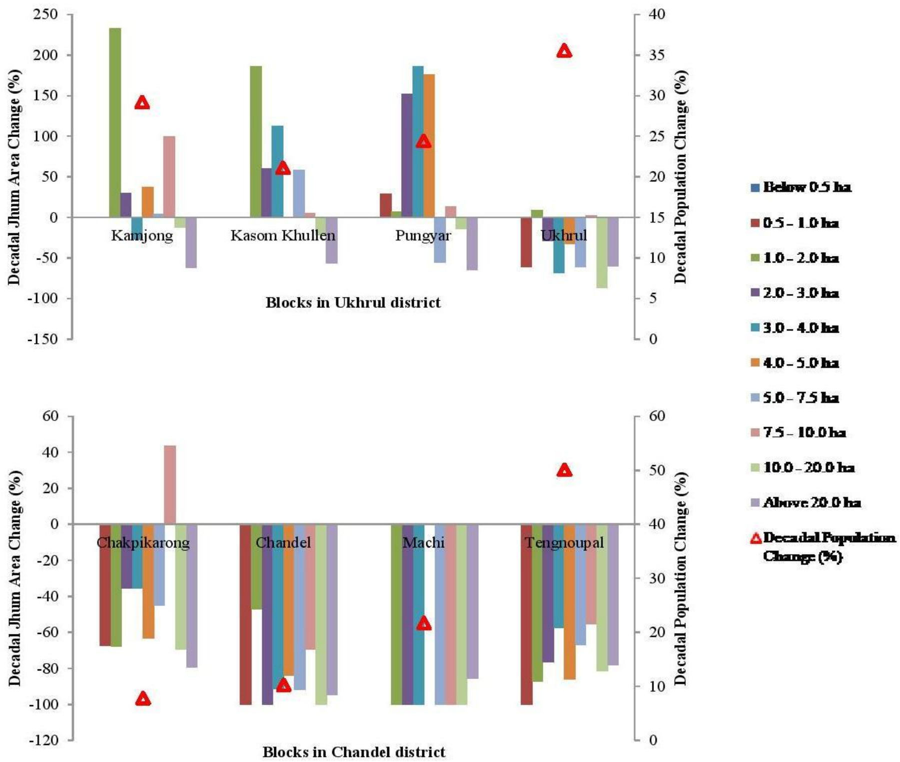


Figure 4.24: Relation between decadal jhum area change (%) and decadal population change (%) in Manipur from 2001 to 2011.

All the blocks in Chandel district has experienced a decrease in jhum area in all land holding classes except in Chakpikarong block where an increase of 43.63% of jhum area under Md3 class (7.5–10 ha) was observed. This signifies that with the increase in population, the jhumia's preference of jhum size deviates to Md3 in Chakpikarong block while the practice of shifting cultivation decreased in other blocks of Chandel. In Ukhrul, Kamjong and Kasom Kullen blocks experienced a huge increase of 232.70% and 186.40% of jhum area under S class (1–2 ha) respectively, and 186.61% increase in jhum area under Sm2 class (3–4 ha) in Pungyar block. The percent increased in S and Sm2 classes illustrates the shift to smaller land holdings over the years in Kamjong, Kasom Kullen and Pungyar blocks. Interestingly, no jhum plots could be located in Chingai block of Ukhrul inspite of the population growth. Chandel and Ukhrul blocks, being the districts headquarters, did not show any distinct deviation in jhum size selection from 2001 to 2011 but experienced the highest percent decrease in the area under shifting cultivation (Table 4.12).

Table 4.12: Decadal change in the jhum area and population of Manipur from 2001 to 2011

Ukhrul				Chandel			
Block	Change in no. of polygons (%)	Area change (%)	Population change (%)	Block	Change in no. of polygons (%)	Area Change (%)	Population change (%)
Kamjong	7.14	-47.67	29.22	Chakpikarong	-55.22	-70.62	22.54
Kasom Khullen	8.47	-48.18	21.11	Chandel	-86.25	-93.32	22.29
Chingai	0.00	0.00	23.27	Machi	-93.75	-89.24	16.26
Pungyar	-10.14	-57.09	24.42	Tengnoupal	-74.53	-77.22	23.56
Ukhrul	-45.88	-60.74	35.59				

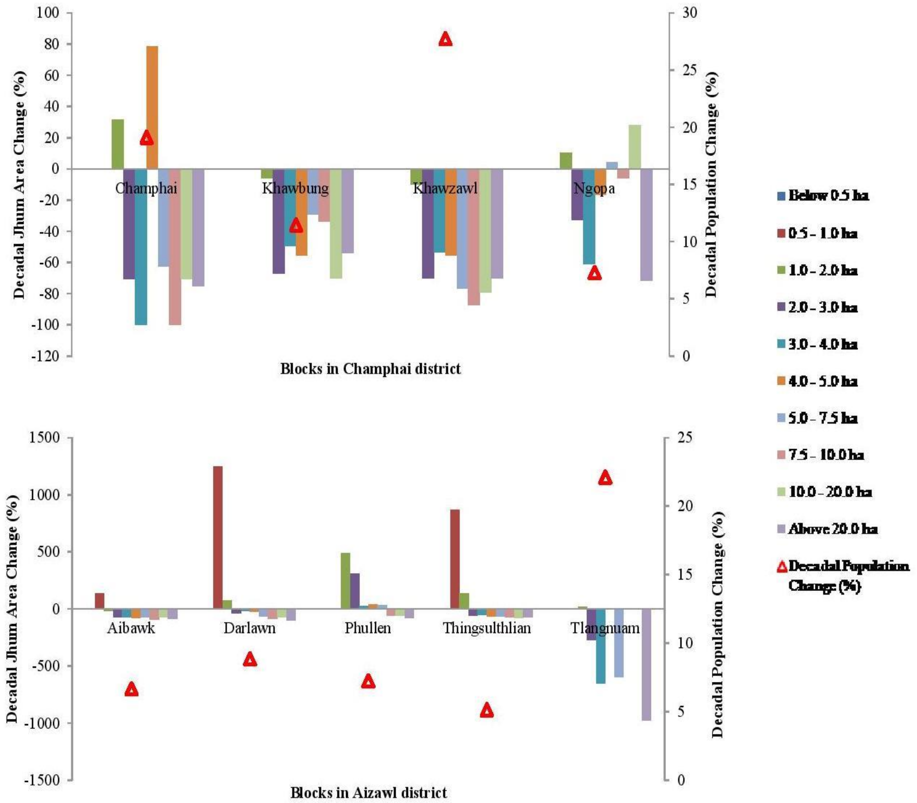


Figure 4.25: Relation between decadal jhum area change (%) and decadal population change (%) in Mizoram from 2001 to 2011.

Khawbung and Khawzawl blocks of Champhai district has experienced a decrease in jhum area in all land holding classes, however Champhai block showed highest percent increase of 78.47% in Md1 class (4 – 5 ha) and 27.82% increase in L1 class (10 – 2- ha) in Ngopa. It can thus be inferred that with the increase in population, the jhumias in Champhai block diverged to jhum fields of size 4 – 5 ha whereas larger jhum size were cultivated in Ngopa. With increase in population of Aizawl district, significant percent increase in M1 class (0.5 – 1 ha) indicates the shift to marginal land holdings over the years in Aibawk, Darlawn and Thingsulthlian blocks, and decline in the jhum area across all land holding class in Tlangnuam block (Figure 4.25). It was also interesting to observe that in Aizawl the number of polygon increased while the area under jhum decreased (Table 4.13). This validates the shift to smaller land holding size in Aizawl which is significantly related to the decadal population growth ($P < 0.001$).

Table 4.13: Decadal change in the jhum area and population of Mizoram from 2001 to 2011

Champhai				**Aizawl**			
Block	Change in no. of polygons (%)	Area change (%)	Population change (%)	Block	Change in no. of polygons (%)	Area Change (%)	Population change (%)
Champhai	-73.81	-74.74	19.13	Aibawk	-22.75	-74.94	6.66
Khawbung	-45.65	-54.31	11.47	Darlawn	5.07	-85.25	8.86
Khawzawl	-61.85	-70.85	27.76	Phullen	167.44	-67.00	7.24
Ngopa	-33.90	-64.99	7.30	Thingsulthlian	82.86	-62.10	5.14
				Tlangnuam	58.33	-329.65	22.12

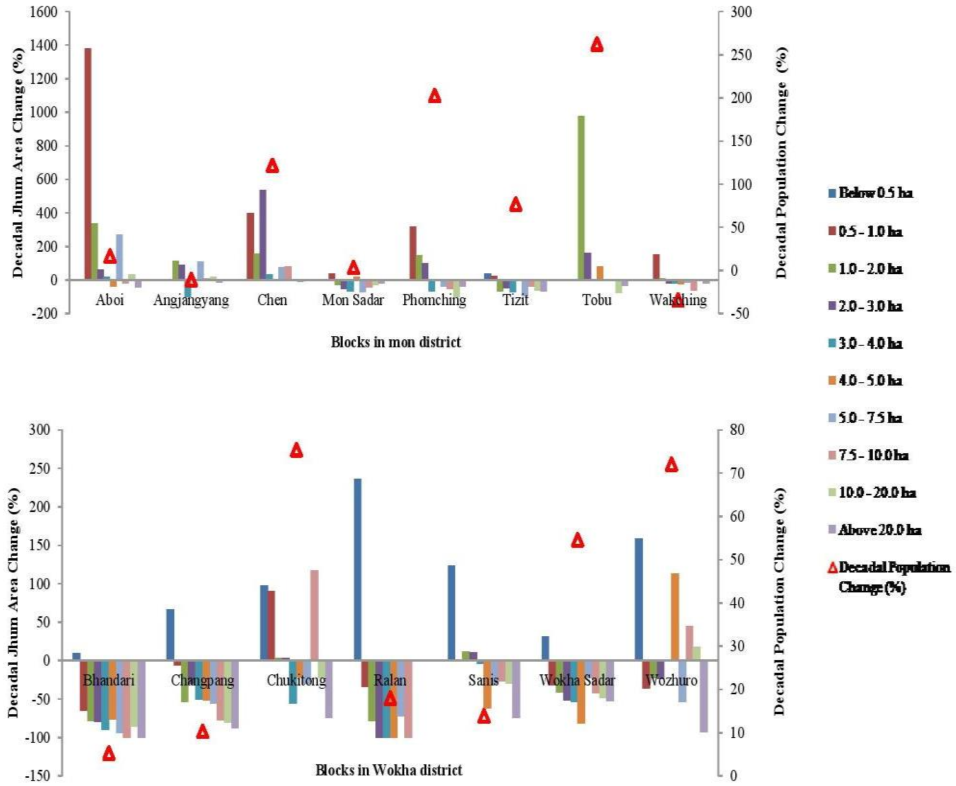


Figure 4.26: Relation between decadal jhum area change (%) and decadal population change (%) in Nagaland from 2001 to 2011.

In Mon district, the distinctive increase in jhum area under M1 class (< 0.5 ha) of Tizit block, M2 class (0.5 – 1 ha) of Aboi, Mon Sadar and Phomching blocks, S class (1 -2 ha) of Tobu block and Sm1 class (2 – 3 ha) of Chen block signifies the shift to marginal and small land holdings as the population of these blocks escalates over the years. On the contrary, decadal decline in the population of Angjangyang and Wakching blocks have resulted in the reduction of jhum area under Sm2 class (3 – 4 ha) and Md3 (7.5 – 10 ha) class respectively. However, this was simultaneously followed by an increase in the jhum area under S class in Angjangyang block by 114.69% and M2 class of Wakching block by 153.75%. All the blocks in Wokha district has experienced a decrease in jhum area in most of the land holding classes suggesting that with the increase in population the practice of jhum cultivation has decreased considerably, and the few percent practicing have switched to marginal land of area < 0.05 ha (Figure 4.26). Decadal population growth has resulted in the decline of polygons numbers and jhum area in Wokha, whereas jhumias have shifted to marginal and small land holdings in Mon (Table 4.14).

Table 4.14: Decadal change in the jhum area and population of Nagaland from 2001 to 2011

Mon				**Wokha**			
Block	Change in no. of polygons (%)	Area change (%)	Population change (%)	Block	Change in no. of polygons (%)	Area Change (%)	Population change (%)
Aboi	88.46	-29.69	16.87	Bhandari	-61.45	-84.46	5.26
Angjangyang	81.83	-10.35	-10.51	Changpang	-18.18	285.96	10.32
Chen	212.50	1.02	121.85	Chukitong	8.13	-52.76	75.42
Mon Sadar	-11.40	-21.06	3.55	Ralan	-51.06	-78.91	17.98
Phomching	37.84	-39.03	202.68	Sanis	1.81	-50.33	13.90
Tizit	-48.30	-64.20	76.98	Wokha Sadar	-37.44	-50.48	54.60
Tobu	127.27	-33.29	262.47	Wozhuro	-5.41	-64.58	72.08
Wakching	14.16	-15.76	-33.92				

4.5 Discussion

The prevailing cropping period in the study area is one to two years which corresponds with previous studies done by Sharma (1998) and Satapathy et al. (2003) in the North-East region of India. Over the study period, there was a declined in area under jhum. Similar trend was reported in the Wasteland Atlas of India 2005, 2010, 2011 and further supported by related works of Chakraborty et al. (2015), Nongkynrih et al. (2018), Thong et al. (2018a, 2019a) and Das et al. (2021) in North-East India. The jhum patch size in the study area varied from 0.1 ha to more than 1100 ha. Since polygons were digitized based on the spectral similarities and continuity of boundary, two or more adjoining jhum lands may have been considered as a single large size jhum patch. Community and clan owned jhum land were also placed in large size jhum land class.

The spatial distribution of majority jhum patches in gentle slope and lower elevation classes corresponds to the findings of Susana and Mario (2004), Sarma et al. (2013), Nongkynrih et al. (2018) and Sarkar et al. (2021) which states that such areas are easily accessible and thereby highly preferred by jhumias. The differences in isolation period and intensity change with aspect of the site which explains for the spatial distribution of jhum patches in every aspect class. However, the study area experienced larger part of its jhum area under SE and E facing aspect which corresponds with the findings of Nongkynrih et al. (2018).

The prevalent jhum size of Ukhrul is 1 – 2 ha and 5 – 7.5 ha in Chandel and Champhai. In addition, Wokha is dominated by jhum plots of 0.5 – 1 ha size and Aizawl and Mon with 1 – 2 ha jhum plots. After performing post classification, the prevailing jhum cycle in Ukhrul and Chandel is 10–14 years and 9–13 years respectively. Champhai and Aizawl showed lesser jhum cycle years of 9-11 and 7-10 respectively. However, the least prevailing jhum cycle was found in Mon and Wokha with 5-7 years jhum cycle. On the contrary, several workers (Toky and Ramakrishnan, 1981; Singh et al., 2003; Tiwari, 2003; Tripathi and Barik, 2003; Jeeva et al., 2006) reported the shortening of jhum cycle to 4–5 years in North-East India with different approach but not based on satellite time series analysis. Therefore, with cropping period of two years, the corresponding fallow period was found to be 8–12 years, 7–11 years, 7-9 years and 5-8 years in Ukhrul, Chandel, Champhai and Aizawl respectively. Mon and Wokha had fallow period duration of 4-7 years.

The decrease in area under shifting cultivation with increase in population signifies that most of the farmers are giving up shifting cultivation and adapting permanent horticultural or plantation crops which correspond with the findings of Choudhury and Sundriyal (2003). Government initiatives to generate employment through Mahatma Gandhi National Rural Employment Guarantee Act (MGNERGA) may also be one of the many reason for the decline in the number of jhum fields in the study area. This can be supported by the Ministry of Rural Development district report on MGNREGA, where 42.60–80.32% of Ukhrul's block population, 16.49–58.31% of Chandel's block population, 22.05 – 38.64% of Champhai's block population, 1.81 – 58.21% of Aizawl's block population, 11.70 – 65.15% of Mon's block population and 17.49 – 96.87% of Wokha's block population were enrolled for Job Cards. Furthermore, the impact of rural-urban migration in Angjangyang and Wakching blocks in Mon can be observed with the jhumias adapting to smaller land holdings due to shortage of human labour.

Chapter 5

Influence of socio-economic factors on the existing trend of shifting cultivation practice

5.1 Introduction

Shifting cultivation (locally known as 'jhum') is a predominant agricultural practice for most of the communities inhabiting the upland in northeast India. It is the major land use and main economic activity for the tribal population of this region. However, population explosion and emergence of new generation of farmers have increased the demand for cultivable lands and resulted in the reduction of the fallow period. At the present time, the transformation of this traditional subsistence system to market oriented agriculture production is the key reason for the shortening of the fallow period. This has led to pressure on resources and thus the productivity of land through land degradation, increase in soil erosion, hydrological imbalance and forest degradation, all contributing to the reduction in yield and food insecurity (Toky and Ramakrishnan, 1981; Schmidt-Vogt, 1998).

In the last few decades, population growth, expansion of trade, economic and social change coupled with governments' effort to change jhum to more intensive agriculture or other land uses with an aim to conserve biodiversity, and preserve ecosystem services have resulted in discontinuance of jhum in North-East India. Recent studies reported the decline in area under shifting cultivation in the region (Chakraborty et al., 2015; Sarma et al., 2015; Nongkynrih et al. 2018; Rao et al., 2018; Riahtam et al., 2018; Thong et al., 2018a, 2019a; Das et al., 2021). Shifting cultivation nevertheless contributes 86% of the total cultivated land in North-East India. Till date there is no definite reliable information on the extent of shifting cultivation in terms of area covered or number of persons engaged in it. However, as per an old ICAR review the total estimated area under shifting cultivation in this region was 5.42 lakh hectares and about 26.441 lakh tribal populations were engaged in it. Report of the Dhebar Commission revealed that nearly 5.41 lakh hectares of area are annually covered by shifting cultivation and about 25.89 lakh tribal populations are dependent on it. Further studies states that jhum is the main economic activity for 0.44 million tribal families and constitutes 83.73 % of the total shifting cultivation area in India (Mandal, 2011; Yadav, 2013).

It was reported that Champhai, Aizawl, Ukhrul, Chandel, Mon and Wokha have 28.52%, 9.06%, 25.05%, 22.35%, 33.73% and 25.17% respectively of its population with farming as the only source of livelihood (Statistical Handbook of Mizoram, Manipur, Nagaland, 2018). Nonetheless, there is still much to know about the extent of jhum in this part of the country, its contribution to farmers' livelihood and the drivers of its changing trends. Till date, no work has been done to analyse the shifting pattern of jhum fields in relation to the socio-economic condition of the farmers practising shifting cultivation in this region. Therefore, this chapter is an attempt to explore the underlying socio-economic drivers for the decline in the jhum area in Champhai and Aizawl districts of Mizoram, Ukhrul and Chandel districts of Manipur and Mon and Wokha districts of Nagaland.

5.2 Materials and methods

5.2.1 Study site

Spatial data on the extent of shifting cultivation in the study area was considered for the selection of 3 villages from each district. The selection was based on the spatial distribution of jhum fields, topography and communities inhabiting the villages (Figure 5.1). Accordingly, Mizos and Peites dominated villages were chosen for data collection in Mizoram. Tangkhul and Kuki tribe dominated villages were selected in Manipur and Konyak and Lotha tribe dominated villages were selected in Nagaland.

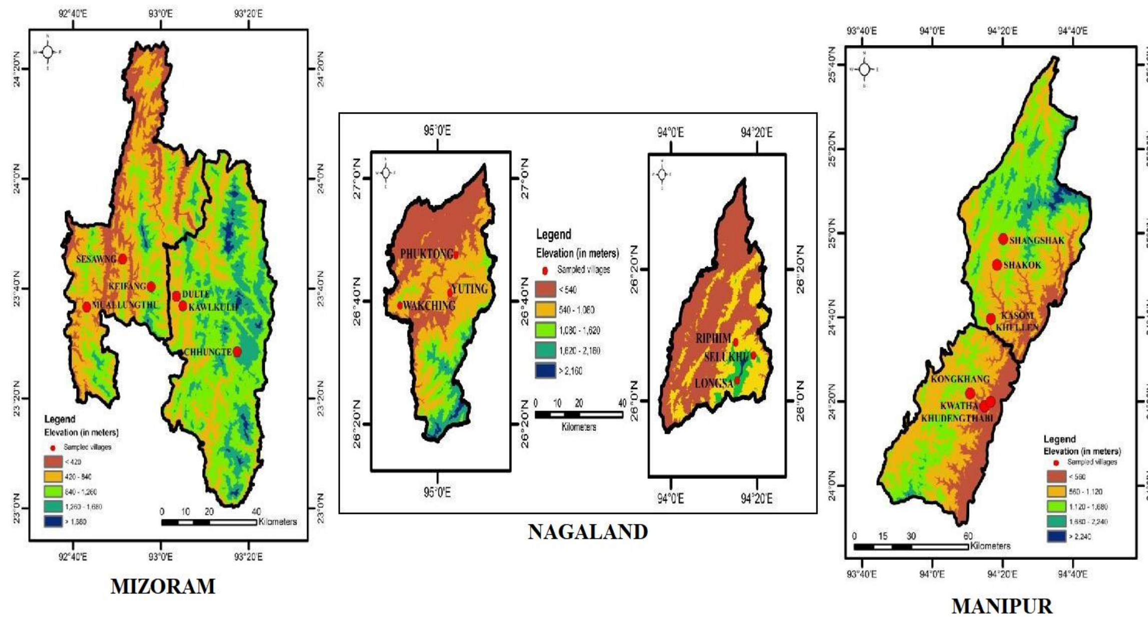


Figure 5.1: Map showing the location of study site within the study area

5.2.2 Data collection

Socio-economic and household data of the shifting cultivators were collected through interviews using questionnaires as well as from secondary sources. A total of 25 households were randomly picked for interview in each village which adds up to 75 households in a district. The survey was focus on households and communities for whom jhum was an integral part of livelihood, social and cultural systems but who through choice or necessity have partly changed their source of livelihood. The questionnaire was addressed to obtain particulars on the household description, income and land ownership, land use types, present jhum practice, farmer's perception towards jhum, Government initiatives to control or improve jhum and its economic influence on the jhumias.

5.3 Statistical analysis

The statistical tools such as frequency, percentage, correlation coefficient and linear regressions were used to analyse the data obtained through the use of structured questionnaires to draw valid inferences. Correlation and linear regression was executed using SPSS version 20.0. Pearson's correlation test was used to understand the nature of relationship between the socio-economic variables and existing jhum cultivation practice, while linear regression was applied to determine the extent of contribution made by the socio-economic variables in explaining the variation in the existing jhum cultivation practice.

5.4 Results

5.4.1 Socio-economic status of the jhumias

The socio-economic attributes of the jhumias in the study site is shown in Table 5.1, 5.4 and 5.7. In Mizoram, majority of the household heads were male above 50 years of age. Over 60% of the respondents had acquired education upto elementary level and therefore the literacy rate of the households exceeds 50%. Dominant family size in the state is 4 – 6 persons wherein Champhai had 1 – 2 members involved in jhum and Aizawl had greater number of family members (3 – 4) involved in jhum. For most of the respondents, the annual income from jhum ranged from ₹50,000 -

₹1,00,000 while few respondents in Champhai were engaged in alternative livelihood options namely horticulture and homegarden.

Table 5.1: Indicators of socio-economic status of jhumias in Mizoram (%)

Socio-economic parameters	**Response**	**Champhai**			**Aizawl**		
		Dulte	Chhungte	Kawlkulh	Sesawng	Muallungthu	Keifang
Age of household head	18 - 35	8	36	32	0	16	28
	36 - 50	40	24	20	28	24	28
	> 50	52	40	48	72	60	44
Gender	Male	100	56	76	96	64	88
	Female	0	44	24	4	36	12
Education level	Illiterate	0	40	16	0	0	0
	Elementary	68	52	68	84	84	72
	Matriculate	24	8	16	8	16	28
	Higher secondary	0	0	0	8	0	0
	Graduate	8	0	0	0	0	0
Occupation	Farmer	96	100	96	100	84	68
	Govt. job	4	0	4	0	8	8
	Business	0	0	0	0	8	24
Religion	Christianity	100	100	100	100	100	100
Social group	ST	100	100	100	100	100	100
Marital status	Married	96	64	96	84	100	88
	Widowed	0	24	4	4	0	8
	Widower	4	12	0	12	0	4
Family size	1-3	8	28	24	8	8	16
	4-6	68	48	60	72	68	68
	7-9	16	24	16	20	20	16
	>9	4	0	0	0	4	0
Literacy rate of the household	< 50 %	0	12	24	0	0	0
	> 50 %	100	88	76	100	100	100
Income from jhum	<50000	0	16	52	0	0	0
	50000-100000	48	28	32	28	52	72
	100000-200000	36	44	16	64	48	12
	>200000	16	12	0	8	0	16
Members involved in Jhum	1- 2	64	68	72	28	16	72
	3 - 4	32	32	28	60	84	28
	> 4	4	0	0	12	0	0
Alternative livelihood options	No option	0	32	84	100	100	100
	Horticulture	56	48	16	0	0	0
	Home gardens	44	20	0	0	0	0

Correlation within the socio-economic parameters in Champhai showed positive relation of age and education of the household head with the income generated from jhum, family members involved in jhum and alternative livelihood options. As the members involved in jhum increases, the income generated also increases and creates other livelihood options (Table 5.2). In Aizawl, however, age of the household head is inversely related to the education and occupation but significantly correlated with the family size, income and members involved in jhum. The number of family members involved in jhum showed a positive relation with the family size and income from jhum (Table 5.3).

Table 5.2: Relation within socio-economic parameters of Champhai

	Age	Education level	Occupation	Family size	Income from jhum	Members involved in jhum	Alternative livelihood options
Age	1	0.216	-0.144	0.159	0.416**	0.477**	0.361**
Education level		1	-0.012	-0.107	0.359**	0.233*	0.455**
Occupation			1	-0.007	0.04	0.055	-0.072
Family size				1	0.161	0.093	0.14
Income from jhum					1	0.408**	0.609**
Members involved in jhum						1	0.366**
Alternative livelihood options							1

* Significant at 0.05, ** Significant at 0.01

Table 5.3: Relation within socio-economic parameters of Aizawl

	Age	Education level	Occupation	Family size	Income from jhum	Members involved in jhum
Age	1	-0.284*	-0.590**	0.391**	0.373**	0.637**
Education level		1	0.195	-0.184	0.186	-0.056
Occupation			1	-0.149	-0.146	-0.454**
Family size				1	0.232*	0.407**
Income from jhum					1	0.337**
Members involved in jhum						1

* Significant at 0.05, ** Significant at 0.01

In Manipur and Nagaland as well, majority of the household heads were male above 50 years of age. About 30.67% of the respondents in Ukhrul were illiterate whereas larger number of respondents in Chandel, Mon and Wokha had studied till elementary level. The prevailing family size is 4 – 6 person where 1 -2 person is permanently involved in jhum as the household do not practice other alternative means of livelihood. As a result, the annual income from jhum in the state of Manipur and Nagaland ranged from ₹1,00,000 - ₹2,00,000 (Table 5.4, 5.7).

Table 5.4: Indicators of socio-economic status of jhumias in Manipur (%)

Socio-economic parameters	**Response**	**Ukhrul**			**Chandel**		
		Shangshak	Shakok	Kasom Khullen	Kongkhang	Khudengthabi	Kwatha
Age of household head	18 - 35	24	20	20	20	24	20
	36 - 50	28	44	40	36	28	44
	> 50	48	36	40	44	48	36
Gender	Male	68	100	88	84	72	96
	Female	32	0	12	16	28	4
Education level	Illiterate	28	32	32	28	36	24
	Elementary	32	28	24	28	28	32
	Matriculate	20	24	32	32	20	24
	Higher secondary	20	8	8	12	16	12
	Graduate	0	8	4	0	0	8
Occupation	Farmer	52	68	56	60	60	60
	Govt. job	28	8	24	16	16	20
	Business	20	24	20	24	24	20
Religion	Christianity	100	100	100	100	100	100
Social group	ST	100	100	100	100	100	100
Marital status	Married	64	100	84	76	68	96
	Widowed	20	0	8	8	16	4
	Widower	16	0	8	16	16	0
Family size	1-3	32	12	28	20	24	20
	4-6	44	56	52	52	40	60
	7-9	20	32	20	24	32	20
	>9	4	0	0	4	4	0
Literacy rate of the household	< 50 %	24	32	28	40	32	24
	> 50 %	76	68	72	60	68	76
Income from jhum	<50000	20	8	16	24	24	4
	50000-100000	28	28	20	20	24	32
	100000-200000	32	44	48	36	32	44
	>200000	20	20	16	20	20	20
Members involved in Jhum	1- 2	44	44	48	48	40	48
	3 - 4	44	40	48	36	48	36
	> 4	12	16	4	16	12	16
Alternative livelihood options	No option	76	16	48	44	64	28
	Horticulture	12	32	28	24	16	28
	Home gardens	12	52	24	32	20	44

Correlation within the socio-economic parameters in Manipur showed significant relation of age with family size and members involved in jhum as well as negative relation with the education and occupation of the household head. Education level of the respondent had direct correlation with the occupation. Both education level and occupation of the respondent had negative association with the family size and members involved in jhum. It was also observed that bigger the family size, more members of the family will be involved in jhum and expand to other livelihood options. A significant correlation was noted between income generated from jhum and the number of family members involved in jhum (Table 5.5, 5.6).

Table 5.5: Relation within socio-economic parameters of Ukhrul

	Age	Education level	Occupation	Family size	Income from jhum	Members involved in jhum	Alternative livelihood options
Age	1	-0.816**	-0.715**	0.658**	0.099	0.740**	0.073
Education level		1	0.769**	-0.665**	-0.095	-0.792**	-0.068
Occupation			1	-0.568**	-0.157	-0.735**	-0.189
Family size				1	0.168	0.708**	0.243*
Income from jhum					1	0.268*	0.219
Members involved in jhum						1	0.129
Alternative livelihood options							1

* Significant at 0.05, ** Significant at 0.01

Table 5.6: Relation within socio-economic parameters of Chandel

	Age	Education	Occupation	Family size	Income from jhum	Members involved in jhum	Alternative livelihood options
Age	1	-0.795**	-0.668**	0.702**	0.129	0.751**	0.122
Education level		1	0.706**	-0.691**	-0.143	-0.812**	-0.165
Occupation			1	-0.586**	-.246*	-0.714**	-0.291*
Family size				1	0.211	0.752**	0.244*
Income from jhum					1	0.317**	0.17
Members involved in jhum						1	0.15
Alternative Livelihood options							1

* Significant at 0.05, ** Significant at 0.01

Table 5.7: Indicators of socio-economic status of jhumias in Nagaland (%)

Socio-economic parameters	Response	Mon			Wokha		
		Wakching	Yuting	Phuktong	Longsa	Riphim	Selukhu
Age of household head	18 - 35	28	24	20	0	24	20
	36 - 50	20	36	36	32	40	28
	> 50	52	40	44	68	36	52
Gender	Male	72	88	92	76	80	88
	Female	28	12	8	24	20	12
Education level	Illiterate	28	20	20	4	16	12
	Elementary	36	32	20	80	64	68
	Matriculate	20	24	44	12	16	16
	Higher secondary	16	20	12	4	0	0
	Graduate	0	4	4	0	4	4
Occupation	Farmer	76	88	72	96	96	98
	Govt. job	8	12	28	4	4	2
	Business	16	0	0	0	0	0
Religion	Christianity	100	100	100	100	100	100
Social group	ST	100	100	100	100	100	100
Marital status	Married	76	88	80	92	80	96
	Widowed	16	4	4	4	20	4
	Widower	8	8	16	4	0	0
Family size	1-3	28	24	24	0	24	16
	4-6	32	52	56	68	60	52
	7-9	40	20	16	28	12	28
	>9	0	4	4	4	4	4
Literacy rate of the household	< 50 %	32	28	32	0	8	20
	> 50 %	68	72	68	100	92	80
Income from Jhum	<50000	24	16	16	0	8	24
	50000-100000	20	28	28	44	44	32
	100000-200000	36	32	40	56	36	36
	>200000	20	24	16	0	12	8
Members involved in Jhum	1- 2	36	44	56	16	56	60
	3 - 4	56	44	32	80	44	36
	> 4	8	12	12	4	0	4
Alternative livelihood options	No option	60	52	40	100	20	44
	Horticulture	16	24	32	0	52	36
	Home gardens	24	24	28	0	28	20

Correlation within socio-economic parameters of Mon displayed a negative relation of age with education and occupation of the household head except for the members involved in jhum (Table 5.8). Education level of the respondent had significant association with the occupation but negative relation with the family size, income generated from jhum and family members involved in jhum. Interestingly, negative connection was manifested between occupation and family size, income from jhum, members involved in jhum and alternate livelihood options. Family size however showed positive relation with income from jhum, members involved in jhum and the alternate source of livelihood. As the number of family members involved in jhum increases, there is also an increase in the income generate from jhum. In Wokha, age of the household head was positively associated with the income generated from jhum and the members involved in jhum (Table 5.9). Education level of the respondent too had significant relation with the income from jhum and alternate livelihood options. Income generated from jhum increases as the number of people involved are increases.

Table 5.8: Relation within socio-economic parameters of Mon

	Age	Education level	Occupation	Family size	Income from jhum	Members involved in jhum	Alternative livelihood options
Age	1	-0.677**	-0.400**	0.703**	0.227	0.713**	0.22
Education level		1	0.461**	-0.626**	-0.305**	-0.793**	-0.178
Occupation			1	-0.468**	-0.228*	-0.441**	-0.347**
Family size				1	0.283*	0.756**	0.328**
Income from jhum					1	0.377**	0.141
Members involved in jhum						1	0.179
Alternative livelihood options							1

* Significant at 0.05, ** Significant at 0.01

Table 5.9: Relation within socio-economic parameters of Wokha

	Age	Education level	Occupation	Family size	Income from jhum	Members involved in jhum	Alternate livelihood options
Age	1	0.149	-0.204	0.109	0.341**	0.526**	0.143
Education level		1	0.034	-0.129	0.406**	0.188	0.376**
Occupation			1	-0.144	0.014	-0.038	-0.036
Family size				1	0.2	0.118	-0.101
Income from jhum					1	0.351**	0.351**
Members involved in jhum						1	0.033
Alternative livelihood options							1

* Significant at 0.05, ** Significant at 0.01

5.4.2 Existing shifting cultivation practice

The characteristic of existing shifting cultivation practice in the study site is represented in Table 5.10, 5.11 and 5.12. In Champhai district of Mizoram, 88% of jhumias practiced jhum in their own land while 70.67% respondents in Aizawl practiced jhum in the communal land. The prominent jhum size in the state is 2 tin. Tin is a local unit of area which is approximately equivalent to 1 acre. In Champhai, large numbers of jhum fields (62.67%) are located at a distance of less than5 km whereas the distance exceeds 15 km in Aizawl. Jhum site selection depends on many parameters, however, soil type was the chief parameter considered during site selection in Aizawl while soil type and distance from home were considered in Champhai. About 9 types of crops are cultivated at a time in Aizawl which increases in case of Champhai. Few percent of jhumias in Champhai adopt management practice and also used pesticides. Maximum of jhumias employ labours at some phase of cultivation thereby increasing the production and percent of produce sold.

Champhai, with higher percentage of produce sold, had 44% of the respondents with daily income of ₹1,000 - ₹2,000 while the daily come was less than ₹1,000 for 57.33% of respondents in Aizawl.

Table 5.10: Indicators of shifting cultivation in Mizoram (%)

Jhum parameters	Response	Champhai			Aizawl		
		Dulte	Chhungte	Kawlkulh	Sesawng	Muallungthu	Keifang
Land ownership	Own land	100	64	100	8	16	32
	Lease Land	0	0	0	20	12	0
	Communal Land	0	36	0	72	72	68
Jhum size	1 Acre	24	40	36	0	0	28
	2 Acre	60	32	64	72	88	72
	3 Acre	16	16	0	16	0	0
	>3 Acre	0	12	0	12	12	0
Distance from home to jhum	<5 km	84	52	52	0	0	0
	5 - 10 km	16	28	48	20	24	16
	11 - 15 km	0	20	0	32	52	28
	> 15 km	0	0	0	48	24	56
Land allocation	Village headman	100	60	80	0	0	0
	Community	0	8	0	84	60	72
	Self- selection	0	32	20	16	40	28
Parameters for site selection	Soil	38	23	24	44	60	44
	Soil & Slope	12	0	36	36	0	16
	Soil & Distance	22	25	40	20	40	40
	Soil, Slope & Distance	12	8	0	0	0	0
	Soil, Distance &	0	8	0	0	0	0

	Aspect						
	Distance	16	24	0	0	0	0
	Soil, Slope & Aspect	0	8	0	0	0	0
	Soil, Slope, Distance & Aspect	0	4	0	0	0	0
Utilization of slashed trees	Firewood	76	84	24	32	16	0
	Firewood & Charcoal	24	0	44	0	0	0
Seed source	Procured	16	20	36	0	0	0
	Relatives	44	40	16	28	28	32
	Self stored	40	40	48	72	72	68
Seed cost	> 500	16	16	28	0	0	0
	< 500	0	4	8	0	0	0
Diversity of crop species	<4	0	0	0	24	44	72
	4 - 6	12	28	12	56	56	28
	7 - 9	32	64	56	20	0	0
	>9	56	8	32	0	0	0
Weeding times	< 3 times	28	16	80	0	0	0
	3-6 times	72	84	20	100	100	100
	> 6 times	0	0	0	0	0	0
Use of fertilizers	Yes	0	0	0	0	0	0
	No	100	100	100	100	100	100
Use of pesticides	Yes	0	20	0	0	0	0
	No	100	80	100	100	100	100
Management practice	Yes	0	84	36	0	0	0
	No	100	16	64	100	100	100
Present cropping period	>2 years	0	36	0	0	0	0
	2 years	0	44	32	0	0	0
	1 year	100	20	68	100	100	100
Cropping period 10-15 years back	1 year	100	44	84	100	100	100
	2 years	0	36	16	0	0	0
	>2 years	0	20	0	0	0	0
Labours involved	Yes	88	36	68	8	12	16
	No	12	64	32	92	88	84
Produce sold	Yes	100	100	76	100	100	100
	No	0	0	24	0	0	0
% sold	1/2	0	0	44	52	52	76
	3/4	100	100	32	48	48	24
Distance from jhum to market	<5 km	88	0	76	0	0	0
	5 - 10 km	12	8	0	36	56	100
	11 - 15 km	0	0	0	28	24	0
	> 15 km	0	92	0	36	20	0
Transportation cost	100-500	0	100	0	36	56	100
	> 500	0	0	0	64	44	0
Daily income	< 1000	52	24	56	68	44	60
	1000-2000	44	68	20	24	40	32
	> 2000	4	8	0	8	16	8

In Manipur, most of the jhumias practiced jhum in the communal land which is allotted by the village head. The prominent jhum size is about 3 acre and situated at about 5 km from the village. Jhum sites were selected specifically based on soil type. More than 9 crops are cultivated at a time in which small number of jhumias used fertilizers and pesticides. Besides, management practices are also adopted in Ukhrul. Over 70% of jhumias hire labours at certain stage of cultivation and sell over ½ of the produce. It cost the jhumias approximately ₹ 500 to transport the produce to market which is at a distance of more than 15 km from the jhum field. The average daily income of the jhumias in the state varies between ₹1,000 - ₹2,000.

Table 5.11: Indicators of shifting cultivation in Manipur (%)

Jhum parameters	**Response**	**Ukhrul**			**Chandel**		
		Shangshak	Shakok	Kasom Khullen	Kongkhang	Khudengthabi	Kwatha
Land ownership	Own land	20	20	16	24	28	12
	Lease Land	36	0	24	20	72	12
	Communal Land	44	80	60	56	0	76
Jhum size	1 Acre	16	16	12	20	16	16
	2 Acre	24	16	24	28	24	16
	3 Acre	28	44	40	32	36	56
	>3 Acre	32	24	24	20	24	12
Distance from home to jhum	<5 km	56	60	64	64	52	64
	5 - 10 km	44	40	36	36	48	36
	11 - 15 km	0	0	0	0	0	0
	> 15 km	0	0	0	0	0	0
Land allocation	Village headman	24	52	52	44	72	44
	Community	36	16	28	32	0	20
	Self- selection	40	32	20	24	28	36
Parameters for site selection	Soil	36	52	36	48	36	52
	Soil & Slope	12	0	4	4	8	4
	Soil & Distance	40	16	40	36	40	16
	Soil, Slope & Distance	12	0	4	4	8	4
	Soil, Distance & Aspect	0	8	4	4	4	4
	Distance	0	24	12	4	4	20
	Soil, Slope & Aspect	0	0	0	0	0	0
	Soil, Slope, Distance & Aspect	0	0	0	0	0	0
Utilization of slashed trees	Firewood	48	48	56	64	52	44
	Firewood & Charcoal	16	24	24	12	16	24
Seed source	Procured	0	0	0	0	0	0
	Relatives	44	60	52	36	36	68

	Self stored	56	40	48	64	64	32
Seed cost	> 500	0	0	0	0	0	0
	< 500	0	0	0	0	0	0
Diversity of crop species	<4	0	0	0	0	0	0
	4 - 6	0	16	8	4	0	16
	7 - 9	52	48	44	44	48	52
	>9	48	36	48	52	52	32
Weeding times	< 3 times	32	32	32	44	36	28
	3-6 times	40	44	44	16	24	60
	> 6 times	28	24	24	40	40	12
Use of fertilizers	Yes	24	32	0	36	32	24
	No	76	68	100	64	68	76
Use of pesticides	Yes	4	0	0	4	4	0
	No	96	100	100	96	96	100
Management practice	Yes	4	0	0	0	0	0
	No	96	100	100	100	100	100
Present cropping period	>2 years	0	0	0	0	0	0
	2 years	0	12	4	8	4	8
	1 year	100	88	96	92	96	92
Cropping period 10-15 years back	1 year	84	92	100	84	88	88
	2 years	16	8	0	16	12	12
	>2 years	0	0	0	0	0	0
Labours involved	Yes	76	84	88	76	76	84
	No	24	16	12	24	24	16
Produce sold	Yes	48	84	68	72	60	72
	No	52	16	32	28	40	28
% sold	1/2	24	60	36	52	36	48
	3/4	24	24	32	20	24	24
Distance from jhum to market	<5 km	0	0	0	0	0	0
	5 - 10 km	0	0	0	0	0	0
	11 - 15 km	0	0	0	0	0	0
	> 15 km	48	84	68	72	60	72
Transportation cost	100-500	48	84	68	72	60	72
	> 500	0	0	0	0	0	0
Daily income	< 1000	20	24	16	20	20	24
	1000-2000	16	36	32	36	24	28
	> 2000	12	24	20	16	16	20

In Nagaland as well, most of the jhumias practiced jhum in the communal land which is allotted by the village head. The dominant jhum size in Wokha is 2 acre while larger areas (> 3 acre) were cultivated in Mon. Jhum sites were selected based on soil type and are generally at a distance of 5 km. Around 7 – 9 crops are cultivated at a time without usage of any fertilizers and pesticides. Besides, some jhumias adopt management practices. Owing due to larger jhum size in Mon, majority of the respondents employed labours for some part of the year (82.67%) whereas lesser labours were employed in Wokha (54.67%). Jhumias of Mon sold about ½ of their produce while jhumias in Wokha sold ¾ of their produce which gain them daily income of ₹1,000 - ₹2,000.

Table 5.12: Indicators of shifting cultivation in Nagaland (%)

Jhum parameters	**Response**	**Mon**			**Wokha**		
		Wakching	Yuting	Phuktong	Longsa	Riphim	Selukhu
Land ownership	Own land	32	12	20	16	20	24
	Lease Land	0	0	0	0	0	0
	Communal Land	68	88	80	84	80	76
Jhum size	1 Acre	16	24	12	0	40	28
	2 Acre	24	28	32	76	48	64
	3 Acre	16	32	24	8	8	8
	>3 Acre	44	16	32	16	4	0
Distance from home to jhum	<5 km	64	64	56	32	72	76
	5 - 10 km	36	36	44	60	16	24
	11 - 15 km	0	0	0	8	12	0
	> 15 km	0	0	0	0	0	0
Land allocation	Village headman	68	88	80	84	80	76
	Community	0	0	0	0	0	0
	Self- selection	32	12	20	16	20	24
Parameters for site selection	Soil	40	36	44	60	36	36
	Soil & Slope	4	4	8	16	0	28
	Soil & Distance	44	24	28	24	16	28
	Soil, Slope & Distance	4	8	8	0	16	4
	Soil, Distance & Aspect	4	8	4	0	4	0
	Distance	4	20	8	0	16	4
	Soil, Slope & Aspect	0	0	0	0	8	0
	Soil, Slope, Distance & Aspect	0	0	0	0	4	0
Utilization of slashed trees	Firewood	60	52	68	32	76	52
	Firewood & Charcoal	16	16	12	0	8	32
Seed source	Procured	0	0	0	0	20	28
	Relatives	40	52	48	28	32	24
	Self stored	60	48	52	72	48	48
Seed cost	> 500	0	0	0	0	16	20
	< 500	0	0	0	0	4	8
Diversity of crop species	<4	0	0	0	36	0	0
	4 - 6	0	0	8	52	20	12
	7 - 9	52	60	40	12	52	48
	>9	48	40	52	0	28	40
Weeding times	< 3 times	20	40	36	0	32	40
	3-6 times	52	44	40	100	68	60
	> 6 times	28	16	24	0	0	0
Use of fertilizers	Yes	0	0	0	0	0	0
	No	100	100	100	100	100	100

Use of pesticides	Yes	0	0	0	0	0	0
	No	100	100	100	100	100	100
Management practice	Yes	24	0	16	100	44	20
	No	76	100	84	0	56	80
Present cropping period	> 2 years	0	0	0	0	0	0
	2 years	8	12	4	0	20	16
	1 year	92	88	96	100	80	84
Cropping period 10-15 years back	1 year	96	84	80	100	68	92
	2 years	4	16	20	0	24	8
	>2 years	0	0	0	0	8	0
Labours involved	Yes	80	88	80	4	56	76
	No	20	12	20	96	44	24
Produce sold	Yes	64	72	76	100	100	92
	No	36	28	24	0	0	8
% sold	1/2	36	40	56	56	0	20
	3/4	28	32	20	44	100	72
Distance from jhum to market	<5 km	0	0	0	0	0	0
	5 - 10 km	0	0	0	0	0	0
	11 - 15 km	0	0	76	0	0	0
	> 15 km	64	72	0	100	100	92
Transportation cost	100-500	64	72	76	100	100	92
	> 500	0	0	0	0	0	0
Daily income	< 1000	12	16	12	16	16	8
	1000-2000	32	32	32	36	56	44
	> 2000	20	24	32	48	28	40

5.4.3 Association between socio-economic parameters and existing jhum practice

The relations of socio-economic factors with the existing shifting cultivation practice in the study area are presented in following tables. In Champhai, socio-economic parameters namely occupation and family size did not show association with any of the indicators of existing jhum practice. However, a positive relation was found between the seed source and each socio-economic parameter (Table 5.13). Jhum size was positively related with all socio-economic parameter except the age, and crop diversity was also positively related with all socio-economic parameter except with the land ownership.

In Aizawl, there was no relation of the alternate livelihood options with the parameters of existing shifting cultivation practice. The age of the household head and the number of family members involved in jhum was directly associated with the existing jhum practice (Table 5.14). Income generated from jhum too was found to be positively related with existing jhum practice except with the labours involved during the process of cultivation. As such, the labours involved in jhum was significantly related to the age, education, occupation, family size, family members involved in jhum and land ownership.

In Ukhrul, the age of the household head showed a positive relation with the labours involved in the process of jhum cultivation and produce sold and a negative relation with usage of fertilizers and distance from jhum to market (Table 5.15). Furthermore, education and occupation of the respondent were negatively associated with jhum size, distance from home to jhum, crop diversity, produce sold, labours involved and positively associated to distance from jhum to market. Number of family members involved in jhum also displayed a significant correlation with jhum size, distance from home to jhum, produce sold, labours involved and distance from jhum to market.

However, in Chandel, education level of the household head and the family size showed contradictory relation with jhum size, distance from home to jhum, use of fertilizers, produce sold, labours involved and distance from jhum to market (Table 5.16). Both income from jhum and members involved in jhum had positive relation with jhum size, produce sold, labours involved but negative relation with distance from jhum to market.

Table 5.13: Relation between socio-economic factors and the parameters for shifting cultivation practice in Champhai

	Jhum size	Distance (home to jhum)	Seed source	Crop diversity	Weeding times	Pesticides usage	Management practices	Present cropping period	Produce sold	Labours involved	Distance (jhum to market)
Age	0.2	0.183	0.388**	0.465**	0.02	0.330**	0.146	-0.118	-0.256*	0.177	-0.073
Education level	0.289*	0.233*	0.335**	0.265*	-0.083	0.159	0.378**	0.199	0.044	-0.089	-0.249*
Income from jhum	0.345**	0.183	0.367**	0.379**	0.345**	0.198	0.101	-0.242*	0.358**	0.134	0.302**
Members involved in jhum	0.269*	0.304**	0.415**	0.285*	0.018	0.179	0.055	-0.102	-0.197	0.334**	0.062
Alternative livelihood options	0.420**	0.107	0.343**	0.280*	0.309**	0.151	0.245*	-0.061	-0.323**	0.062	0.169
Land ownership	0.287*	0.602**	0.275*	-0.079	0.143	0.099	-0.201	-0.678**	-0.109	0.321**	0.535**

* Significant at 0.05, ** Significant at 0.01

Table 5.14: Relation between socio-economic factors and the parameters for shifting cultivation practice in Aizawl

	Jhum size	Distance (home to jhum)	Seed source	Crop diversity	Labours involved	Distance (jhum to market)
Age	0.298**	0.419**	0.266*	0.333**	0.612**	0.414**
Education level	0.123	0.042	-0.062	0.173	-0.254*	0.025
Occupation	-0.198	-0.125	-0.006	-0.171	-0.231*	-0.236*
Family size	0.275*	0.127	-0.084	0.196	0.351**	0.310**
Income from jhum	0.276*	0.366**	0.304**	0.521**	0.204	0.385**
Members involved in jhum	0.434**	0.251*	0.231*	0.457**	0.436**	0.587**
Land ownership	0.209	0.115	0.387**	0.127	0.295*	0.229*

*Significant at 0.05, ** Significant at 0.01

In Mon, education and occupation of the household head showed negative relation with jhum size, distance from home to jhum, produce sold, labours involved and a positive relation with distance from jhum to market (Table 5.17). Age and income also indicates direct relation with produce sold, labours involved and a negative relation with distance from jhum to market. Besides, family size and number of members involved in jhum had positive correlation with jhum size, distance from home to jhum, weeding times, labours involved and negative association with seed source and distance from jhum to market.

Least correlation between socio-economic parameters and existing jhum practice was observed in Wokha district (Table 5.18). Age of the household head was directly related to jhum size, seed source and labours involved. In addition, members involved in jhum was positively related to jhum size, distance from home to jhum, seed source, present cropping period and labours involved for some part of the year. Income generated from jhum was also observed to be significantly related with seed source, crop diversity, distance from jhum to market and produce sold.

Table 5.15: Relation between socio-economic factors and the parameters for shifting cultivation practice in Ukhrul

	Jhum size	Distance (home to jhum)	Parameters (site selection)	Crop diversity	Fertilizers usage	Produce sold	Labours involved	Distance (jhum to market)
Age	0.184	0.213	-0.023	0.212	-0.277*	0.406**	0.478**	-0.406**
Education level	-0.238*	-0.243*	-0.028	-0.304**	0.159	-0.413**	-0.431**	0.413**
Occupation	-0.240*	-0.261*	-0.193	-0.287*	0.159	-0.406**	-0.353**	0.406**
Family size	0.172	0.306**	0.019	-0.021	-.311**	0.168	0.369**	-0.168
Income from jhum	0.217	0.167	-0.079	-0.074	-0.11	0.478**	0.248*	-0.478**
Members involved in jhum	0.255*	0.386**	0.083	0.076	-0.147	0.455**	0.611**	-0.455**
Alternative livelihood options	0.216	0.166	-0.222	-0.233*	-0.137	0.011	0.01	-0.011
Land ownership	-0.107	-0.097	0.375**	0.094	-0.001	0.12	-0.024	-0.12

*Significant at 0.05, ** Significant at 0.01

Table 5.16: Relation between socio-economic factors and the parameters for shifting cultivation practice in Chandel

	Jhum size	Distance (home to jhum)	Parameters (site selection)	Seed source	Weeding times	Fertilizers usage	Pesticides usage	Produce sold	Labours involved	Distance (jhum to market)
Age	0.215	0.198	-0.035	-0.122	0.167	-0.416**	0.046	0.403**	0.531**	-0.403**
Education level	-0.272*	-0.300**	0.004	0.163	-0.233*	0.263*	-0.104	-0.422**	-0.497**	0.422**
Occupation	-0.326**	-0.19	-0.142	0.159	-0.187	0.259*	-0.075	-0.450**	-0.394**	0.450**
Family size	0.249*	0.297**	-0.035	-0.275*	0.226	-0.418**	0.241*	0.257*	0.498**	-0.257*
Income from jhum	0.335**	0.192	-0.119	-0.081	0.023	-0.093	0.267*	0.535**	0.308**	-0.535**
Members involved in jhum	0.270*	0.352**	0.051	-0.215	0.225	-0.205	0.161	0.497**	0.682**	-0.497**
Alternative livelihood options	0.175	0.063	-0.270*	-0.236*	0.141	-0.202	0.165	-0.026	0.042	0.026
Land ownership	0.063	-0.098	0.311**	-0.106	-0.086	-0.029	0.048	0.021	-0.152	-0.021

*Significant at 0.05, ** Significant at 0.01

Table 5.17: Relation between socio-economic factors and the parameters for shifting cultivation practice in Mon

	Jhum size	Distance (home to jhum)	Parameters (site selection)	Seed source	Crop diversity	Weeding times	Produce sold	Labours involved	Distance (jhum to market)
Age	0.261*	0.096	-0.072	-0.217	0.18	0.101	0.411**	0.448**	-0.409**
Education level	-0.292*	-0.240*	0.049	0.156	-0.300**	-0.163	-0.519**	-0.456**	0.488**
Occupation	-0.013	-0.236*	0.047	0.162	0.009	0.095	-0.313**	-0.222	0.306**
Family size	0.303**	0.261*	-0.057	-0.312**	0.101	0.265*	0.293*	0.465**	-0.283*
Income from jhum	0.18	0.227*	-0.06	0.002	0.026	-0.072	0.592**	0.298**	-0.594**
Members involved in jhum	0.346**	0.291*	0.02	-0.287*	0.053	0.290*	0.558**	0.664**	-0.520**
Alternative Livelihood options	0.264*	0.143	-0.181	-0.252*	-0.077	0.114	-0.085	0.055	0.055
Land ownership	-0.034	-0.054	0.318**	-0.03	0.240*	-0.199	0.264*	0.066	-0.283*

*Significant at 0.05, ** Significant at 0.01

Table 5.18: Relation between socio-economic factors and the parameters for shifting cultivation practice in Wokha

	Jhum size	Distance (home to jhum)	Parameters (site selection)	Seed source	Crop diversity	Weeding times	Management practice	Present cropping period	Produce sold	Labours involved	Distance (jhum to market)
Age	0.252*	0.147	-0.024	0.461**	0.004	0.074	0.178	0.133	-0.199	0.284*	0.199
Education	0.222	0.115	-0.051	0.187	0.14	0.114	0.285*	0.188	-0.033	-0.037	0.033
Occupation	-0.153	-0.083	-0.026	-0.127	-0.114	-0.283*	0.124	0.088	-0.039	-0.022	0.039
Family size	0.13	-0.187	-0.269*	0.122	0.097	0.05	0.315**	0.15	-0.159	0.034	0.159
Income from jhum	0.17	0.116	0	0.379**	0.255*	0.168	0.18	0.217	0.312**	0.084	-0.312**
Members involved in jhum	0.375**	0.296**	-0.061	0.537**	-0.106	0.09	0.203	0.247*	-0.179	0.490**	0.179
Alternative Livelihood options	-0.08	-0.158	0.171	0.038	0.612**	-0.082	0.035	0.084	-0.136	-0.364**	0.136
Land ownership	-0.009	-0.377**	-0.046	-0.089	-0.049	0.109	0.146	0.021	0.083	0.013	-0.083

*Significant at 0.05, ** Significant at 0.01

5.4.4 Influence of socio-economic parameters in explaining the variation in the existing jhum practice

The extent of contribution made by the socio-economic variables in explaining the variation in the existing jhum practice is represented in the subsequent tables. In Champhai, 7.5 - 17.2 % variation in the seed source can be explained by all the socio-economic indicators. Furthermore, 7.3 - 11.9 % variation in the jhum size and 7 - 14.4 % variation in the crop diversity were explained by the socio-economic parameters except age of the household head and land ownership (Table 5.19). The maximum contribution of socio-economic parameters on the existing jhum practice was found to be between land ownership and present cropping period (45.9%).

The highest contribution of socio-economic parameters on the existing jhum practice was found to be between age of the household head and labours involved (37.5%) in Aizawl. Besides, 5.3 – 19% variation in the labours involved during the process of jhum can be explained by other socio-economic parameters except income of the household head. In addition, all socio-economic parameters excluding education explained the variation in distance from jhum to market by 5.2 – 34.5 % (Table 5.20).

In Ukhrul, 6.2 – 37.3% variation in labours involved at some part of the year can be explained by age, education, occupation of the household head, family size, income and family members involved in jhum. 2.8 – 22.8% variation in produce sold distance from jhum to market were explained by age, education, occupation of the household head, income from jhum and family members involved in jhum (Table 5.21). The highest contribution of socio-economic parameters on the existing jhum practice was found to be between the numbers of family members involved in jhum and the labours involved during some part of the year (37.3%).

Table 5.19: Contribution of socio-economic variables in explaining the variation in the existing jhum practice in Champhai

	Jhum size	Distance (home to jhum)	Seed source	Crop diversity	Weeding times	Pesticides usage	Management practice	Present cropping period	Produce sold	Labours involved	Distance (jhum to market)
Age	0.04	0.034	0.151**	0.216**	0	0.109**	0.021	0.014	0.066*	0.031	0.005
Education level	0.083*	0.054*	0.112**	0.070*	0.007	0.025	0.143**	0.04	0.002	0.008	0.062*
Income from jhum	0.119**	0.033	0.135**	0.144**	0.119**	0.039	0.01	0.058*	0.128**	0.018	0.091**
Members involved in jhum	0.073*	0.092**	0.172**	0.081*	0	0.032	0.003	0.01	0.039	0.112**	0.004
Alternative livelihood options	0.117**	0.011	0.117**	0.079*	0.096**	0.023	0.060*	0.004	0.104**	0.004	0.028
Land ownership	0.082*	0.362**	0.075**	0.006	0.021	0.01	0.04	0.459**	0.012	0.103**	0.287**

*Significant at 0.05, **Significant at 0.01

Table 5.20: Contribution of socio-economic variables in explaining the variation in the existing jhum practice in Aizawl

	Jhum size	Distance (home to jhum)	Seed source	Crop diversity	Labours involved	Distance (jhum to market)
Age	0.089**	0.176**	0.071*	0.111**	0.375**	0.171**
Education level	0.015	0.002	0.004	0.03	0.065*	0.001
Occupation	0.039	0.016	0	0.029	0.053*	0.056*
Family size	0.076*	0.016	0.007	0.038	0.124**	0.096**
Income from jhum	0.076*	0.134**	0.093**	0.272**	0.042	0.149**
Members involved in jhum	0.188**	0.063*	0.054*	0.209**	0.190**	0.345**
Land ownership	0.044	0.013	0.150**	0.016	0.087*	0.052*

*Significant at 0.05, **Significant at 0.01

Table 5.21: Contribution of socio-economic variables in explaining the variation in the existing jhum practice in Ukhrul

	Jhum size	Distance (home to jhum)	Parameters (site selection)	Crop diversity	Fertilizers usage	Produce sold	Labours involved	Distance (jhum to market)
Age	0.034	0.045	0.001	0.045	0.077*	0.165**	0.229**	0.165**
Education level	0.057	0.059*	0.001	0.092**	0.025	0.170**	0.186**	0.170**
Occupation	0.058*	0.068*	0.037	0.082*	0.025	0.165**	0.125**	0.165**
Family size	0.03	0.094**	0	0	0.097**	0.028	0.136**	0.028
Income from jhum	0.047	0.028	0.006	0.005	0.012	0.228**	0.062*	0.228**
Members involved in jhum	0.065*	0.149**	0.007	0.006	0.022	0.207**	0.373**	0.207**
Alternative livelihood options	0.046	0.027	0.049	0.054*	0.019	0	0	0
Land ownership	0.011	0.009	0.141**	0.009	0	0.014	0.001	0.014

*Significant at 0.05, **Significant at 0.01

Table 5.22: Contribution of socio-economic variables in explaining the variation in the existing jhum practice in Chandel

	Jhum size	Distance (home to jhum)	Parameters (site selection)	Seed source	Weeding times	Fertilizers usage	Pesticides usage	Produce sold	Labours involved	Distance (jhum to market)
Age	0.046	0.039	0.001	0.015	0.028	0.173**	0.002	0.163**	0.282**	0.163**
Education level	0.074*	0.090**	0	0.026	0.054*	0.069*	0.011	0.178**	0.247**	0.178**
Occupation	0.106**	0.036	0.02	0.025	0.035	0.067*	0.006	0.202**	0.155**	0.202**
Family size	0.062*	0.088**	0.001	0.076*	0.051	0.174**	0.058*	0.066*	0.248**	0.066*
Income from jhum	0.112**	0.037	0.014	0.007	0.001	0.009	0.071*	0.286**	0.095**	0.286**
Members involved in jhum	0.073*	0.124**	0.003	0.046	0.051	0.042	0.026	0.247**	0.465**	0.247**
Alternative livelihood options	0.03	0.004	0.073*	0.056*	0.02	0.041	0.027	0.001	0.002	0.001
Land ownership	0.004	0.01	0.097**	0.011	0.007	0.001	0.002	0	0.023	0

*Significant at 0.05, **Significant at 0.01

In Chandel, 6.6 – 28.6% variation in the produce sold and distance from jhum to market and 9.5 – 46.5% variation in labours involved during some part of the year can be explained by socio-economic parameters namely age, education, occupation of the household head, family size, income from jhum and number of family members involved in Jhum (Table 5.22). Furthermore, parameters such as education and occupation of the household head, family size, income from jhum and members involved in jhum explains for 6.2 – 11.2% variation in the jhum size. The highest contribution of socio-economic parameters on the existing jhum practice was found to be between the number of family members involved in jhum and labours involved (46.5%).

In Mon, the highest contribution of socio-economic parameters on the existing jhum practice was found to be between the family members involved in jhum and labours involved (44.1%) (Table 5.23). In addition, 7 – 35% variation in the produce sold and 8 – 35.2% variation in the distance from jhum to market can be explained by several indicators such as age, education, occupation, family size, income from jhum, members involved in jhum, alternative livelihood options and land ownership.

Wokha showed the least correlation between socio-economic parameters and existing jhum practice, however, the highest contribution of socio-economic parameters on the existing jhum practice was found to be between alternative livelihood options and crop diversity (37.4%) (Table 5.24). Income from jhum could explain14.4%, 6.5% and 9.7% variation in seed source, crop diversity and produce sold and respectively.

Furthermore, 14.1%, 8.8%, 28.9%, 6.1% and 24% variation in the jhum size, distance from home to jhum, seed source, present cropping period and labour involved was explained by the number of family members involved in jhum.

Table 5.23: Contribution of socio-economic variables in explaining the variation in the existing jhum practice in Mon

	Jhum size	Distance (home to jhum)	Parameters (site selection)	Seed source	Crop diversity	Weeding times	Produce sold	Labours involved	Distance (jhum to market)
Age	0.068*	0.009	0.005	0.047	0.033	0.01	0.169**	0.200**	0.168**
Education level	0.085*	0.058*	0.002	0.024	0.090**	0.026	0.269**	0.208**	0.238**
Occupation	0	0.056*	0.002	0.026	0	0.009	0.098**	0.049	0.094**
Family size	0.092**	0.068*	0.003	0.098**	0.01	0.070*	0.086*	0.216**	0.080*
Income from jhum	0.032	0.052*	0.004	0	0.001	0.005	0.350**	0.089**	0.352**
Members involved In jhum	0.120**	0.085*	0	0.083*	0.003	0.084*	0.311**	0.441**	0.270**
Alternative livelihood options	0.070*	0.02	0.033	0.064*	0.006	0.013	0.007	0.003	0.003
Land ownership	0.001	0.003	0.101**	0.001	0.058*	0.04	0.070*	0.004	0.080*

*Significant at 0.05, **Significant at 0.01

Table 5.24: Contribution of socio-economic variables in explaining the variation in the existing jhum practice in Wokha

	Jhum size	Distance (home to jhum)	Parameters (site selection)	Seed source	Crop diversity	Weeding times	Management practice	Present cropping period	Produce sold	Labours involved	Distance (jhum to market)
Age	0.063*	0.021	0.001	0.213**	0	0.005	0.032	0.018	0.04	0.081*	0.04
Education level	0.049	0.013	0.003	0.035	0.02	0.013	0.081*	0.035	0.001	0.001	0.001
Occupation	0.023	0.007	0.001	0.016	0.013	0.080*	0.015	0.008	0.002	0	0.002
Family size	0.017	0.035	0.072*	0.015	0.009	0.002	0.099*	0.023	0.025	0.001	0.025
Income from jhum	0.029	0.013	0	0.144**	0.065*	0.028	0.032	0.047	0.097**	0.007	0.097**
Members involved in jhum	0.141**	0.088*	0.004	0.289**	0.011	0.008	0.041	0.061*	0.032	0.240**	0.032
Alternative livelihood options	0.006	0.025	0.029	0.001	0.374**	0.007	0.001	0.007	0.018	0.133**	0.018
Land ownership	0	0.142**	0.002	0.008	0.002	0.012	0.021	0	0.007	0	0.007

*Significant at 0.05, **Significant at 0.01

5.4.5 Farmer's perception towards jhum

Most of the jhumias are aware of the detrimental effect of jhum on the environment (86%) however they practice jhum as they do not have any other options for their livelihood sustainability. Besides, jhum is the most suitable system adopted in response to the natural environment and physiographic condition of the region. Factors which contribute to the continuation of jhum in the region are: jhum provides different products all throughout the year (94%), Polyculture/mixed cropping nature of jhum control against pest infestation and crop failure (89%), Cultural ethics are associated with jhum (93%) and low/no cost involved in the process of production (82%).

5.4.6 Policy framework from government to control/improve jhum and its economical impact on the jhumias

Inspite of many central and state government sponsored schemes to replace Jhum with settled agriculture in the North-Eastern states. Some of the institutions within and outside the state have also attempted to demonstrate sustainable models of Jhum cultivation, with different measures. However, on conducting the survey, jhumias of Manipur and Nagaland were not aware of any such schemes from the government. Only in Mizoram the respondents were aware of the New Land Use Policy (NLUP) introduced by the government of Mizoram. The main aim of the policy is to put an end to the practices of shifting cultivation by giving the farmers alternative sustainable land-based permanent occupation and stable income to the families. Under NLUP, majority of the respondents were allotted land for horticulture (68 %) while others were engaged in plantation (16%), carpentry (8%) and poultry (8%). However, the jhumias response towards NLUP was not satisfying, the reason being, it involves input of high monetary assistance and the outcome is a long duration, leaving them with no source of income meanwhile.

5.5 Discussion

In the study area, the male dominated households with age above 50 years corresponds with the findings of Datta et al. (2014), Punitha et al. (2016), Thong et al. (2018b). The education qualification of majority jhumias was found to be in agreement with the results of sati (2019). Least percentage of illiterate respondents was observed in Mizoram which is verified with the high literacy rate of the state. Similar prominent family size of 4-6 members was also observed by Datta et al. (2014), Thong et al. (2018b) and Sati (2019) in this part of the country. The prevalent jhum size in this study also accord with the findings of Thong et al. (2019b). Greater part of the respondents earned an annual income of >50000 which corresponds with the findings of Thong et al. (2018b) and Sati (2019). Apart from jhum, horticulture was practiced by most of the jhumias to meet their financial needs. Punitha et al (2016) also reported the implementation of horticultural activity particularly fruits orchard development for livelihood diversification.

The produce from jhum is essentially organic as little or no chemical pesticides or fertilizers are used in the process of production which is as per the findings of Kerkhoff and Sharma (2006). More than 65% of the jhumias sold their produce in the market and hence improves the income status of the family. This was supported by the study of Loison and Bignebat (2017) who stated that those farmers who had market access like transport accessibility, ability to sell farm products in the market helps in income diversification.

Datta et al. (2014) also found a positive relation of education and income with livelihood status of the jhumias. And therefore, in the current context, the educated jhumias will have more knowledge about new technologies and management strategies to find better returns. Furthermore, the significant relation between jhum size and income explains that the income from jhum is more if the jhum size is more. Education and occupation of the household head contributes to the increase in the jhum size, however, contradictory result was represented by Thong et al. (2019b).

In the present study, age and family size of the respondent showed relation with the distance from home to jhum which is at par with the findings of Thong et al. (2018b).

Chapter 6

Socio-Economic Vulnerability Assessment of shifting cultivators (jhumias) amidst the changing climate in north-east India

6.1 Introduction

Globally, community livelihoods stand threatened by climate change. The vulnerability to climate change is often high for the poor and marginalized segment of the society in developing countries with natural and land-based livelihood options (Singh and Chudasama, 2017). The widespread poverty, lack of technological development, lesser adaptation options and resources to mitigate the adverse effect of climate change makes these countries all the more vulnerable (Nath and Behera, 2011; Parmesan and Yohe, 2003). Amidst the developing countries, India has 68.9% of its rural population chiefly relying on agriculture for their subsistence and livelihood, with 82% farmers being small and marginal (Census of India, 2011). Agriculture prevails as a significant part of the country's economy because of its food security, employment creation and poverty alleviation. Indian agriculture is highly climate-sensitive with 56% of its total cultivated area under rain-fed agriculture (Venkateswarlu and Prasad, 2012). These rain-fed areas experience multiple biophysical and socio-economic limitations including unpredictable rainfall, low input of technology, low accessibility of draft power and meagre resource farmers (Venkateswarlu, 2011). Since the North-East region lack irrigation facility, any major variation in temperature and precipitation effects the agricultural production and can probably jeopardize the food and livelihood security of the populace (Kumar et al., 2011). The on-going variations in climate have adversely affected the water quantity, biodiversity, ecosystem structure, ecological processes and intensified natural disasters in the highlands (Basharat et al. 2016). Therefore, to sustain in the hilly region is a great adversity considering the high dependence on natural resources and existing poverty (de Sherbinin et al., 2018). Besides, in the past few years, the significance of vulnerability and adaptive capacity has often been cited to elucidate the social issues of climate change which ultimately leads to socio-economic discrimination in the society (Ahmed et al., 2009; Fussel and Klein, 2006).

Because of the topographically varied hilly terrain in northeast India, the environment and socio-economic conditions differ significantly over relatively short distance. The rural population is most susceptible to natural disasters and they need to adapt to the changing environment for their survival and improved livelihood possibilities (Gentle and Maraseni, 2012). The association between jhumias and their physical and social surroundings is comprehensively consolidated and scrutinized to assess the vulnerability. In fact, the socio-economic vulnerability of the jhumias can be assessed as a function of the nature, magnitude and degree of climate variation to which they are exposed, their sensitivity and capacity to adapt with the negative impacts (Barnett and Adger, 2007; McCarthy et al., 2001). It has been an integral part of social system which escalates on the unavailability of natural resources and economic development (O'Brien et al., 2007).

In context of the present study, exposure is the nature and extent to which a system encounters environmental stress and sensitivity is the prevailing socio-economic state of the jhumias which surge their vulnerability to changing climate. Corresponding to common perspective, we define adaptive capacity as the ability and resources of the jhumias to respond to external hazards. Vulnerability, however, is site-specific and differs across region with regard to social structure, economic status and policy making (Cutter et al., 2000; Patt et al., 2009). Several researchers have therefore proposed localized evaluation of socio-economic vulnerability, particularly at community level so as to better understand the basic attribute underlying vulnerability of communities within a district or region (Ahsan and Warner, 2014; Below et al. 2012). As socio-economic status of the household affects the aptitude to cope with the changing environment (Adger, 2006), relevant contributing indicators were aggregated to form an index. Indicator based Socio-economic Vulnerability Index was utilized to manage accretion of a series of noticeable contributing variables into a scalar variable (Hinkel, 2011). In this chapter, it is attempted to utilize household data to examine the jhumias susceptibility to the changing climate by using the lens of socio-economic vulnerability frameworks.

6.2 Materials and methods

6.2.1 Study site

Spatial data on the extent of shifting cultivation in the study area was considered for the selection of 3 villages from each district. Since this study is conducted in 2 districts each across 3 states, the total sampled villages add up to 18. The sampled villages were:

- Dulte, Chhungte and Kawlkulh in Champhai
- Sesawng, Muallungthu and Keifang in Aizawl
- Shangshak, Shakok and Kasom khullen in Ukhrul
- Kongkhang, Khudengthabi and Kwatha in Chandel
- Wakching, Yuting and Phuktong in Mon
- Longsa, Riphim and Selukhu in Wokha

6.2.2 Data collection

The qualitative method of Rapid Rural Appraisal (RRA) was implemented to obtain the insights into creating the socio-economic vulnerability and better understand the contributing indicators of vulnerability in the study area. Socio-economic and household data of jhumias were assembled through secondary as well as primary source (by administering pre-tested questionnaire survey). A total of 25 households in each village were picked by using systematic random sampling for primary data collection. Thus, a total of 450 households were selected for extensive study. The survey gathered information on the demographic characteristics, income and land ownership, and existing jhum practice, effect of changing climate on jhum and adaptation methods. The jhumias were also asked questions on their observation concerning patterns of temperature and rainfall over the last 10-15 years.

6.2.3 Normalization of indicators

Based on literature review and household survey, the indicators of socio-economic vulnerability were developed. These indicators were inclusive and pertinent in rural perspective, and thus represented the household’s status in relation to the climate variability and extremes (Hahn et al., 2009). A sum total of 24 indicators were identified to evaluate vulnerability. Each indicator had contrasting units and scales;

hence, the indicators were normalized based on the functional relation between the indicators and vulnerability (Yadava and Sinha, 2020).

$$Index\ (S_v) = \frac{S_v - S_{min}}{S_{max} - S_{min}}$$

where, S_v is the average value of the indicator. S_{max} and S_{min} are the maximum and minimum values of the indicator at the respondent level.

6.2.4 Identification of components and selection of indicators

Components are case specific and may possibly be qualitative attributes of the system which are manifested quantitatively by using proxies (Deems, 2010). Under each component there are multiple contributing indicators which are variable and estimate of a system functioning with reference to significant and observable attributes (Holling et al., 2003). To identify the significant indicators, we applied Principal Component Analysis (PCA) for extraction and Varimax method for rotation of the factors in Statistical Package for Social science (SPSS version 20.0). It was prerequisite that the communality value had to be more than 0.6 to keep the indicators in the factor analysis model (Mohanty et al., 2016). Therefore, 6 indicators with lower communalities (<0.6) were removed from the list of indicators. Based on all three dimensions of vulnerability, we developed multiple components specific to the context of the study (Table 6.1), with 2 components for exposure, 3 for sensitivity and 4 for adaptive capacity.

6.2.5 Weight assignment

We employed the statistical approach which is considered to be an equitable way of assigning weight to each component. Uniform weight was considered for all the 3 dimensions ($W_{Exposure} = W_{Sensitivity} = W_{Adaptive\ capacity} = 33.33$), but assigned different weights among indicators due their high variability in influencing vulnerability. PCA was used to group the indicators and assign weights based on the presumption that common factors explain the variance. Varimax rotation was executed on all the selected indicators and the factors with eigenvalue greater than 1 were incorporated in the analysis. The rotation factor analysis developed 9 components from 18 indicators, with high loading value, which described about 54%, 64% and 57% of the

Table 6.1: Vulnerability dimensions, components and indicators used for SeVI analysis of jhumias

Vulnerability dimensions	Component	Indicators	Source	Effect	Rationale
Exposure	Precipitation variability and hazard	Change in rainfall	Simane et al., 2016	+	Larger change or frequency in climate leads to higher exposure
		Storm		+	
	Temperature variability and hazard	Change in temperature		+	
		Landslide		+	
Sensitivity	Cropping period	Present cropping period	Thong et al., 2018b	-	Increase in the cropping period reduces the clearing of forest for jhum and hence reduce manual labour
		Cropping period 10-15 years back	Tawnenga et al., 1997	-	
	Yield	Annual total production	Simane et al., 2016	-	Lesser the crop productivity, higher will be the livelihood sensitivity
		Change in productivity	Ashalatha et al., 2012	+	climate change shortens the growing period of the crops and thereby effects the productivity
	Seed source	Seed source	Punitha et al.,2018	+	Storage of good germplasm for further plantation reduces the sensitivity of gene pool depletion
Adaptive capacity	Education	Education level	Piya et al., 2012	-	Well educated household head will have a stable job and hence can invest in adaptation strategies
		Literacy rate of the household	Jamir et al., 2013	-	Literacy rate among the farmers provides information on the overall management of jhum
		Members involved in jhum	Datta et al., 2014	-	More human capital, greater will be the adaptive capacity
	Accessibility and labour force	Labours involved		-	
		Distance (home to jhum)	Dalle et al., 2011	+	Shorter distance are easily accessible for transportation of produce
	Income	Income from Jhum	Jamir et al., 2013	-	Returns from Jhum is indicative of the well-being and adaptive capacity of the farmer
		Alternative livelihood options	Lalrinsangpui et al., 2016	-	Non-farm income have more profit efficient
	Land management	Land ownership	Punitha et al.,2018	-	Individually owned land have higher capacity in addressing adversities
		Management practice	Thong et al., 2018b	-	Adapting proper management practices improves the physical adaptive capacity

total cumulative variance in the dataset for exposure, sensitivity and adaptive capacity respectively (Table 6.2).

Weight for each component under the vulnerability dimensions was determined using the formula:

$$Weight(W_c) = \frac{E_c \times 33.33}{\sum_{c=1}^{n} E_c}$$

where, W_c is the weight of component 'c', E_c is the eigenvalue of cth component and n is the number of components in a particular dimension (Value of n = 2,3,4 for exposure, sensitivity and adaptive capacity respectively). We considered 33.33 as the weight of single dimension so that the cumulative weights for all the components in vulnerability assessment come to 100 (Table 6.3).

6.2.6 Socio-economic Vulnerability Index (SeVI)

The SeVI was calculated using a Composite Indicator Framework method which comprises of three main dimensions viz. Exposure, sensitivity and adaptive capacity (Krishnamurthy et al., 2011; Parry et al., 2007). Nine (9) components with 18 indicators were used to determine the SeVI. We applied the following equation, extracted from life expectancy index formula (UNDP, 2007) to standardise each indicator to acquire an index score for each village 'i'.

$$Indicator\ index\ score_i = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

where, X_i is the value of indicator for the household/community and X_{max} and X_{min} are the maximum and minimum values of indicators for the household/community. Since SeVI is a positive function of the system's exposure and sensitivity and a negative function of the adaptive capacity (Ford and Smit, 2004).We applied inverse value (1 minus indicator score) for index calculation for adaptive capacity.

Once the indicator index score was obtained, relative weight acquired from PCA was multiplied with concerned indicator to get the weighted indicator score.

$$Weighted\ indicator\ score(WIS)_j = (Indicator\ index\ score)_j \times (Average\ weight)_j$$

where, j indicates the indicators within each component.

After determining the weighted score for each contributing indicator, we continued to calculate the component vulnerability score by averaging the weighted scores of all indicators within the same component.

$$CoV_i = \frac{\sum_{j=1}^{n}(WIS)_j}{\sum_{j=1}^{n}(Average\ weight)_j}$$

where, CoV_i is the component vulnerability score for each village and WIS_j is the weighted index score of each indicator. Then, dimension vulnerability index for exposure, sensitivity and adaptive capacity were evaluated.

$$DM_{Exposure_i} = \frac{\sum_{k=1}^{2} CoV_k}{2}$$

$$DM_{Sensitivity_i} = \frac{\sum_{l=1}^{3} CoV_l}{3}$$

$$DM_{Adaptive\ capacity_i} = \frac{\sum_{m=1}^{4} CoV_m}{4}$$

Where k, l and m represent the number of components under the three dimensions of vulnerability, and i indicate the village. Lastly, the village level composite Socio-economic Vulnerability Index (SeVI) was derived as

$$SeVI_i = \frac{DM_{Exposure_i} + DM_{Sensitivity_i} + DM_{Adaptive\ capacity_i}}{3}$$

The SeVI is scaled from 0 to 1 with 0 being the least vulnerable and 1 being the most vulnerable. The detailed procedure adopted for the present study is represented in Figure 6.1.

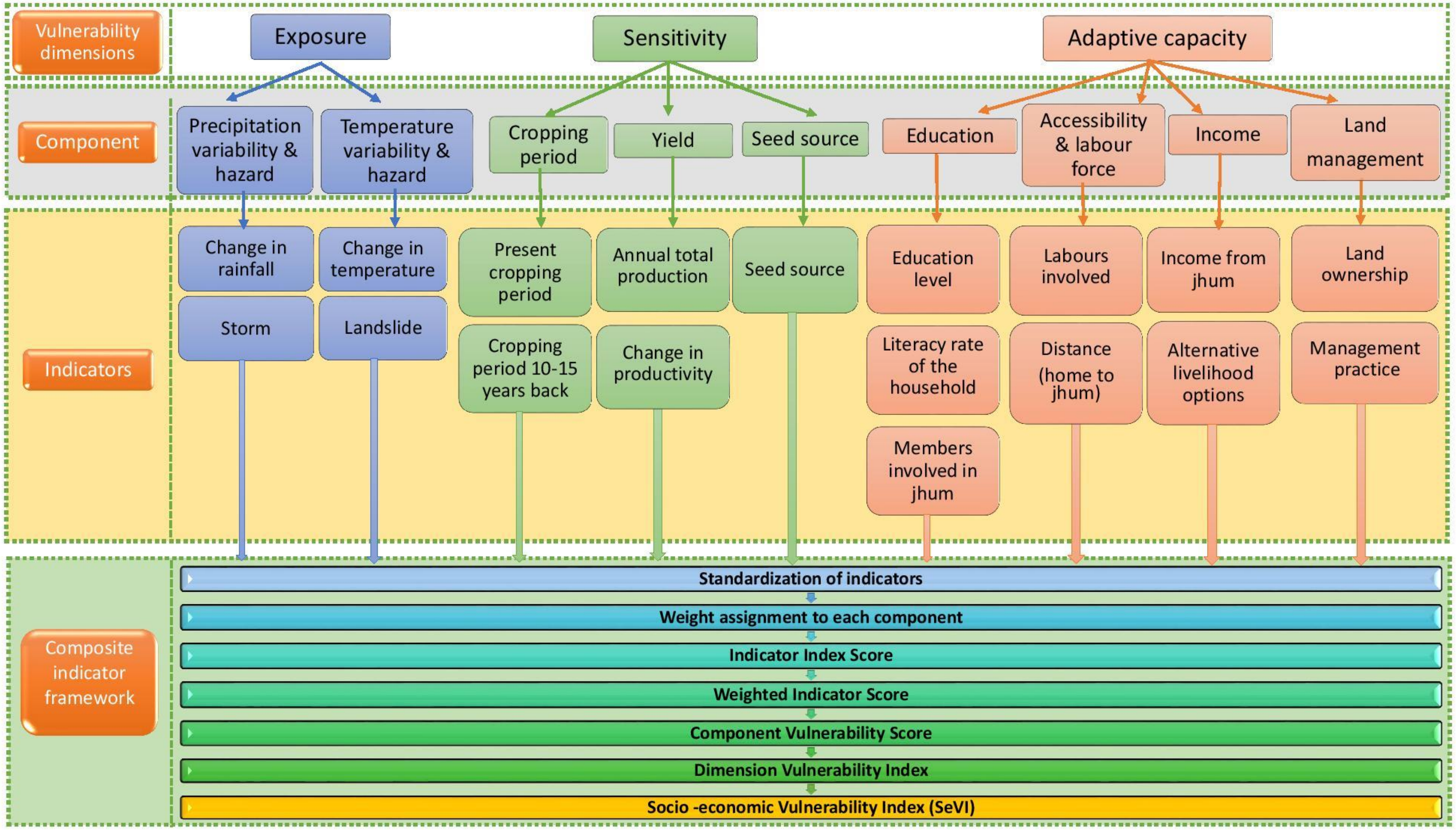


Figure 6.1: Methodological framework of the study

Table 6.2: Outcome of Principal Component Analysis (PCA) for eigenvalues greater than 1

Component	Initial eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings			Weight
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	
EXPOSURE										
1	1.1	27.53	27.53	1.1	27.53	27.53	1.09	27.26	27.26	50.81
2	1.05	26.13	53.66	1.05	26.13	53.66	1.06	26.4	53.66	49.19
SENSITIVITY										
1	1.63	27.2	27.2	1.63	27.2	27.2	1.61	26.78	26.78	41.68
2	1.18	19.64	46.85	1.18	19.64	46.85	1.18	19.72	46.51	30.69
3	1.05	17.41	64.26	1.05	17.41	64.26	1.07	17.75	64.26	27.63
ADAPTIVE CAPACITY										
1	3.25	23.24	23.24	3.25	23.24	23.24	2.49	17.8	17.8	31.44
2	1.94	13.88	37.11	1.94	13.88	37.11	2.21	15.76	33.56	27.85
3	1.69	12.06	49.17	1.69	12.06	49.17	1.64	11.71	45.28	20.69
4	1.04	7.44	56.61	1.04	7.44	56.61	1.59	11.33	56.61	20.02

Table 6.3: Components and indicators developed after PCA

Components (% of variance)	Weight	Indicators
Precipitation variability and hazard (27.26%)	16.93	Change in rainfall
		Storm
Temperature variability and hazard (26.40%)	16.4	Change in temperature
		Landslide
Cropping period (26.78%)	13.89	Present cropping period
		Cropping period 10-15 years back
Yield (19.72%)	10.23	Annual total production
		Change in productivity
Seed source (17.75%)	9.21	Seed source
Education (17.80%)	10.48	Education level
		Literacy rate of the household
		Members involved In jhum
Accessibility and labour force (15.76%)	9.28	Labours involved
		Distance (home to jhum)
Income (11.71%)	6.9	Income from Jhum
		Alternative livelihood options
Land management (11.33%)	6.67	Land ownership
		Management practice

6.3 Results

Significant demographic and socio-economic attributes of the respondent households across 18 villages in the study area is represented in the preceding chapter (Table 5.1, 5.4 and 5.7). The result of data analysis for socio-economic vulnerability was described in 3 segments viz. Component wise vulnerability, dimension wise vulnerability and socio-economic vulnerability.

6.3.1 Component wise vulnerability

The indicator index scores for individual indicators comprised the SeVI and distributed over the nine (9) components is represented in Table 6.4. The score of each component is represented in Table 6.5 and is addressed briefly in the subsequent sections.

6.3.1.1 Precipitation variability and hazard

Variability in precipitation and related events were highest in Shakok with component variability score of 0.73 and lowest in Chhungte with a score of 0.42. Over the last few decades Champhai district have experienced a decrease in the annual rainfall (Guhathekurta et al., 2020) while Ukhrul have observed a considerable increase in precipitation (SAPCC, 2013). Events of storm related disaster have been reported in Ukhrul during the months of April – September (DDMP, 2019-2020).

6.3.1.2 Temperature variability and hazard

Keifang with a score of 0.42 and Muallungthu as well as Khudengthabi with 0.20 were the most and least vulnerable villages to the changing temperature and associated hazard respectively. Time series analysis of Mizoram and Manipur revealed an increasing trend in the average annual temperature (Jain et al., 2013; SAPCC, 2013; Rathore et al., 2020). With increase in temperature coupled with unusual weather condition, Keifang located at higher degree of slope than Muallungthu and Khudengthabi is more prone to landslides.

Table 6.4: Indicator index score of the villages

Indicators	Champhai			Aizawl			Ukhrul			Chandel			Mon			Wokha		
	Du	Ch	Ka	Se	Mu	Ke	Shg	Sh	KK	Ko	Kh	Kw	Wa	Yu	Ph	Lo	Ri	Se
Change in rainfall	0.54	0.56	0.67	0.54	0.62	0.58	0.58	0.66	0.50	0.68	0.50	0.5	0.6	0.6	0.54	0.54	0.5	0.54
Storm	0.48	0.28	0.59	0.64	0.55	0.55	0.52	0.8	0.83	0.52	0.72	0.65	0.6	0.64	0.63	0.61	0.73	0.72
Change in temperature	0.16	0.08	0.16	0	0.12	0.28	0.24	0.08	0	0.16	0.12	0.24	0	0.12	0.12	0.24	0	0.24
Landslide	0.47	0.64	0.5	0.61	0.28	0.55	0.43	0.64	0.61	0.25	0.27	0.45	0.44	0.51	0.6	0.39	0.52	0.41
Present cropping period	1	0.42	0.84	1	1	1	0.44	0.94	0.98	0.96	0.98	0.96	0.96	0.94	0.98	1	0.9	0.92
Cropping period 10-15 years back	0	0.38	0.08	0	0	0	1	0.04	0	0.08	0.06	0.06	0.02	0.08	0.1	0	0.2	0.04
Annual total production	0.32	0.2	0	0.43	0.56	0.45	0.45	0.51	0.44	0.55	0.52	0.44	0.52	0.51	0.49	0.52	0.28	0.16
Change in productivity	0.48	0.28	0.56	0.42	0.52	0.38	0.44	0.42	0.56	0.34	0.46	0.48	0.52	0.46	0.6	0.58	0.5	0.6
Seed source	0.62	0.6	0.56	0.86	0.86	0.84	0.78	0.7	0.74	0.82	0.82	0.66	0.8	0.74	0.76	0.86	0.64	0.600
Education level	0.63	0.83	0.75	0.69	0.71	0.69	0.67	0.67	0.68	0.68	0.71	0.63	0.69	0.61	0.60	0.71	0.72	0.71
Literacy rate of the household	0	0.12	0.24	0	0	0	0.24	0.32	0.28	0.40	0.32	0.24	0.32	0.28	0.32	0	0.08	0.20
Members involved in jhum	0.80	0.84	0.86	0.58	0.58	0.86	0.66	0.64	0.72	0.66	0.64	0.66	0.64	0.66	0.72	0.56	0.78	0.78
Labours involved	0.95	0.77	0.84	0.24	0.33	0.20	0.85	0.87	0.88	0.88	0.84	0.88	0.88	0.88	0.85	0.75	0.87	0.92
Distance (home to jhum)	0.88	0.36	0.68	0.08	0.12	0.16	0.76	0.84	0.88	0.76	0.76	0.84	0.80	0.88	0.80	0.04	0.56	0.76
Income from jhum	0.44	0.49	0.79	0.40	0.51	0.52	0.49	0.41	0.45	0.49	0.51	0.40	0.49	0.45	0.48	0.48	0.49	0.57
Alternative livelihood options	0.28	0.56	0.92	1	1	1	0.82	0.32	0.62	0.56	0.72	0.42	0.68	0.64	0.56	1	0.46	0.62
Land ownership	1	0.64	1	0.18	0.22	0.32	0.38	0.20	0.28	0.34	0.64	0.18	0.32	0.12	0.20	0.16	0.20	0.24
Management practice	0	0.84	0.36	0	0	0	0.04	0	0	0	0	0	0.24	0	0.16	0	0.44	0.20

Du = Dulte, Ch = Chhungte, Ka = Kawlkulh, Se = Sesawng, Mu = Muallungthu, Ke = Keifang, Shg = Shangshak, Sh = Shakok, KK = Kasom Khullen, Ko = Kongkhang, Kh = Khudengthabi, Kw = Kwatha, Wa = Wakching, Yu = Yuting, Ph = Phuktong, Lo = Longsa, Ri = Riphim, Se = Selukhu

Table 6.5: Component vulnerability, Dimension vulnerability and overall SeVI scores of the villages under Champhai and Aizawl districts of Mizoram, Ukhrul and Chandel districts of Manipur, Mon and Wokha districts of Nagaland

Vulnerability Dimension	**Components**	**Component Vulnerability Score (CoV)**																	
		Champhai			**Aizawl**			**Ukhrul**			**Chandel**			**Mon**			**Wokha**		
		Du	Ch	Ka	Se	Mu	Ke	Shg	Sh	KK	Ko	Kh	Kw	Wa	Yu	Ph	Lo	Ri	Se
Exposure	Precipitation variability and hazard	0.51	0.42	0.63	0.59	0.58	0.57	0.55	0.73	0.67	0.60	0.61	0.58	0.60	0.62	0.59	0.58	0.62	0.63
	Temperature variability and hazard	0.32	0.36	0.33	0.31	0.20	0.42	0.34	0.36	0.31	0.21	0.20	0.35	0.22	0.32	0.36	0.32	0.26	0.33
Sensitivity	Cropping period	0.50	0.40	0.46	0.50	0.50	0.50	0.72	0.49	0.49	0.52	0.52	0.51	0.49	0.51	0.54	0.50	0.55	0.48
	Yield	0.40	0.24	0.28	0.43	0.54	0.42	0.45	0.47	0.50	0.45	0.49	0.46	0.52	0.49	0.55	0.55	0.39	0.38
	Seed source	0.62	0.60	0.56	0.86	0.86	0.84	0.78	0.70	0.74	0.82	0.82	0.66	0.80	0.74	0.76	0.86	0.64	0.60
Adaptive capacity	Education	0.48	0.60	0.62	0.42	0.43	0.52	0.52	0.54	0.56	0.58	0.56	0.51	0.55	0.52	0.55	0.42	0.53	0.56
	Accessibility and labour force	0.92	0.57	0.76	0.16	0.23	0.18	0.81	0.86	0.88	0.82	0.80	0.86	0.84	0.88	0.83	0.40	0.72	0.84
	Income	0.36	0.53	0.86	0.70	0.76	0.76	0.66	0.37	0.54	0.53	0.62	0.41	0.59	0.55	0.52	0.74	0.48	0.60
	Land management	0.50	0.74	0.68	0.09	0.11	0.16	0.21	0.10	0.14	0.17	0.32	0.09	0.28	0.06	0.18	0.08	0.32	0.22
Dimension Vulnerability ($DM_{Exposure}$)		0.41	0.39	0.48	0.45	0.39	0.49	0.44	0.55	0.49	0.40	0.40	0.46	0.41	0.47	0.47	0.45	0.44	0.48
Dimension Vulnerability ($DM_{Sensitivity}$)		0.51	0.41	0.43	0.60	0.63	0.59	0.65	0.55	0.58	0.60	0.61	0.54	0.60	0.58	0.62	0.64	0.53	0.49
Dimension Vulnerability ($DM_{Adaptive\ Capacity}$)		0.56	0.61	0.73	0.34	0.38	0.40	0.55	0.47	0.53	0.52	0.57	0.47	0.56	0.50	0.52	0.41	0.51	0.55
Overall Socio-economic Vulnerability Index (SeVI)		0.49	0.47	0.55	0.46	0.47	0.49	0.55	0.52	0.53	0.51	0.53	0.49	0.53	0.52	0.54	0.50	0.49	0.51

Du = Dulte, Ch = Chhungte, Ka = Kawlkulh, Se = Sesawng, Mu = Muallungthu, Ke = Keifang, Shg = Shangshak, Sh = Shakok, KK = Kasom Khullen, Ko = Kongkhang, Kh = Khudengthabi, Kw = Kwatha, Wa = Wakching, Yu = Yuting, Ph = Phuktong, Lo = Longsa, Ri = Riphim, Se = Selukhu

6.3.1.3 Cropping period

Shangshak village with component vulnerability score of 0.72 was most vulnerable to the effect of climate change on the cropping period and Chhungte was the least vulnerable with score of 0.40. Indicators of this component showed that since several years, the cropping period in Shangshak has been 1-2 years while about 20% of respondents continued with 3rd year cropping and beyond in Chhungte.

6.3.1.4 Yield

Contradictory to the cropping period, the component vulnerability for yield was prominent in Phuktong and Longsa with a score of 0.55 and lowest score of 0.24 in Chhungte. The indicators under this component in Mon, Wokha and Champhai district is represented below (Table 6.6)

Table 6.6: Indicators of yield component in Mon, Wokha and Champhai (%)

Yield	Response	Mon			Wokha			Champhai		
		Wa	Yu	Ph	Lo	Ri	Se	Du	Ch	Ka
Annual total production	<2.5 tonnes	16	4	12	24	44	72	44	52	100
	2.5 - 5 tonnes	24	48	40	2	36	16	28	36	0
	5.1 - 7.5 tonnes	48	40	36	64	12	4	16	12	0
	>7.5 tonnes	12	8	12	8	8	8	12	0	0
Change in productivity	Increased	36	32	28	24	32	20	28	56	28
	Same	24	44	24	36	36	40	48	32	32
	Decreased	40	24	48	40	32	40	24	12	40

Wa = Wakching, Yu = Yuting, Ph = Phuktong, Lo = Longsa, Ri = Riphim, Se = Selukhu, Du = Dulte, Ch = Chhungte, Ka = Kawlkulh,

Indicators within this component showed that despite the annual total production of more than 7.5 tonnes in Phuktong and Longsa, these villages reported more than 40% of respondents who had experienced a decrease in the productivity from jhum over the years. In the contrary, greater percent of the jhumias (56%) in Chhungte experienced an increase in the productivity from jhum over time.

6.3.1.5 Seed source

Sesawng, Muallungthu and Longsa with a score of 0.86 and Kawlkulh with a score of 0.56 were the most and least vulnerable villages under this component. Kawlkulh has some percent of jhumias (36%) access to the market to procure seeds for sowing in the jhum while the rest of the village depends on self-stored seeds and those collected from the relatives.

6.3.1.6 Education

Kawlkulh was most vulnerable to the effect of climate change on the education component with a score of 0.62 and Sesawng together with Longsa were least vulnerable with scores of 0.42. The highest education level in Sesawng and Longsa was upto higher secondary which substantiate for cent percent literate jhumias in these villages. Kawlkulh, on the other hand, revealed 16% illiterate respondents and highest education level upto matriculation (16%) with 76% literacy rate.

6.3.1.7 Accessibility and labour force

Dulte with component vulnerability score of 0.92 and Sesawng with a score of 0.16 were the most and least vulnerable villages under this component. The maximum distance from home to jhum fields in Dulte is about 10 Km while it is >15 Km in Sesawng. However, 88% of jhumias in Dulte employ labours at certain part of the year while only 8% of jhumias in Sesawng involved labours in the process of jhum.

6.3.1.8 Income

Kawlkulh was found economically the most vulnerable village (score: 0.86) and Dulte as the least vulnerable village (score: 0.36). The income generated from jhum in Dulte is > ₹200000 while that of Kawlkulh is upto ₹200000. Furthermore, in Dulte about 56% and 44% of jhumias practice horticulture and homegarden as an alternative source of livelihood, while only 16% of jhumias in Kawlkulh practice horticulture as an alternative source of livelihood.

6.3.1.9 Land management

Chhungte was found to be highly vulnerable to the management of jhum with score of 0.74 and Longsa was least vulnerable with a score of 0.08. In Longsa, 100 % of the jhumias adopted management practices such as minimum tillage, placement of poles along the contour and raking and mulching. About 84% of jhumias in Chhungte were aware of planting leguminous crops and thus increase the soil fertility.

6.3.2 Dimension wise vulnerability

In the present study, the average dimensional score of either equal or above 0.45 was regarded as a significant contributor towards socio-economic vulnerability of the related area. Hence, sensitivity and adaptive capacity were more dominant dimension than exposure (Figure 6.2).

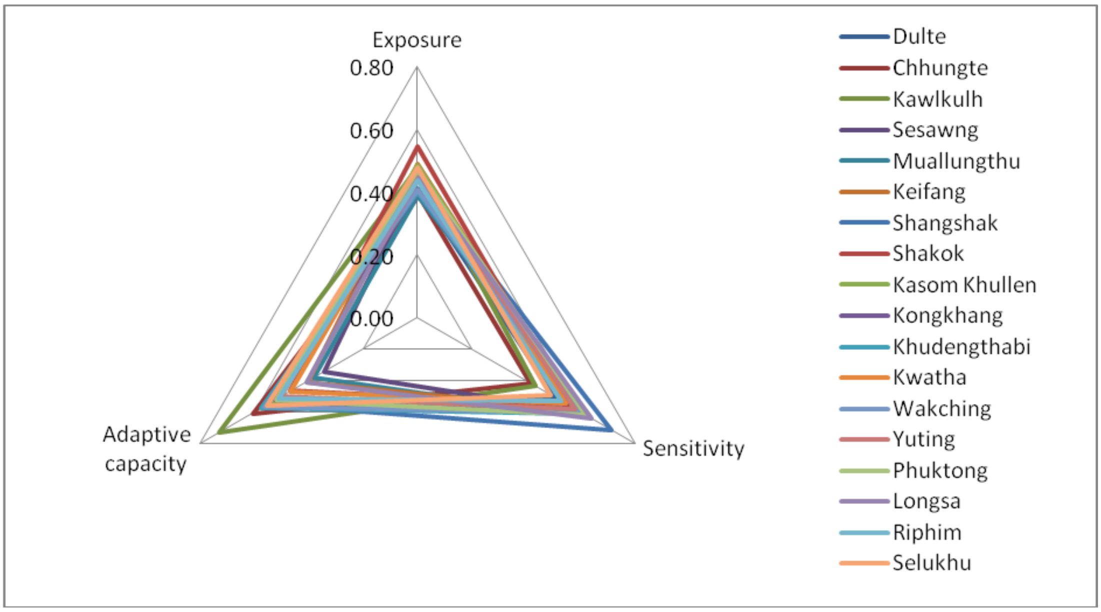


Figure 6.2: Dimension wide vulnerability score

The highest sensitivity score of 0.65 was found in Shangshak followed by Longsa with dimension score of 0.64. However, the lowest score of 0.41 was found in Chhungte. From the past 10 – 15 years until recently, the cropping period in Shangshak has been one year but currently the productivity in these villages was observed to be declining for majority of the jhumias. Chhungte, however, utilized jhum fields upto 3rd year and beyond and the yield have also increased over the years which could be dint of implementing management practices that maintains soil fertility. For adaptive capacity, Kawlkulh showed the highest score of 0.73 followed by Chhungte with a score of 0.61 while the lowest score of 0.34 was found in Sesawng. The entire respondents in Kawlkulh practiced jhum in their own land of size not bigger than 2 acre. Majority of the respondents (64%) do not implement any resource conservation measures which results in poor yield, disease and pests attack on the crops, low quality produce, and hence fall short to adapt to the changing environment. In view of exposure dimension, the highest score of 0.49 was observed in Keifang and Kasom Khullen followed by Kawlkulh and selukhu (score:0.48) while the lowest score of 0.39 were seen in Chhungte and Muallungthu. The increase in temperature along with heavy downpour and storm during the monsoon over the loose colluvial soil type made Keifang and Kasom Khullen all the more exposed to the environmental stress due to climate change.

6.3.3 Socio-economic vulnerability

Based on the final score of Socio-economic Vulnerability Index (SeVI), Shangshak and Kawlkulh was socio-economically the most vulnerable village with a score of 0.55, followed by Phuktong (0.54). On the contrary, the least vulnerable village was Sesawng (0.46) (Table 6.5). A stack graph was constructed to demonstrate the magnitude of individual indicators across villages and within a particular dimension. The value of each dimension ranges from 0 to 6 where proximate to 6 indicates more vulnerability (Figure 6.3, 6.4 and 6.5).

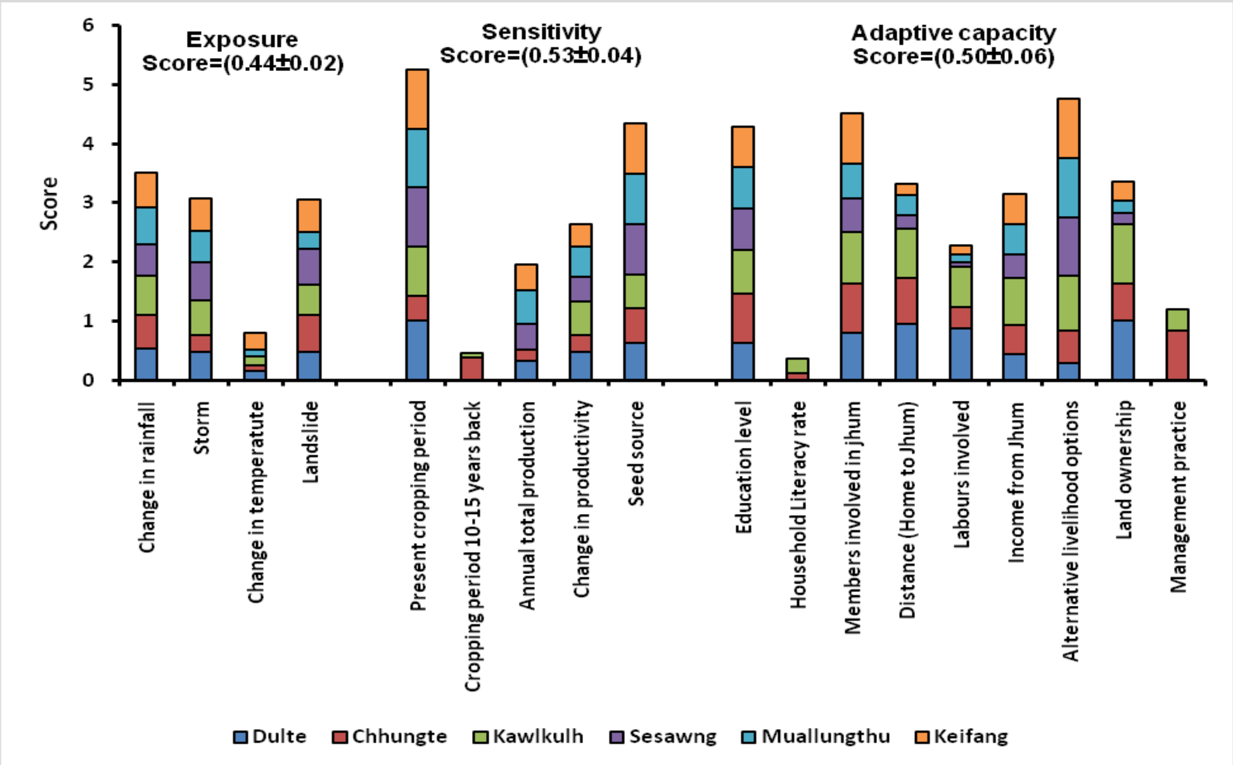


Figure 6.3: Magnitude of indicators in dimensions across villages in Mizoram

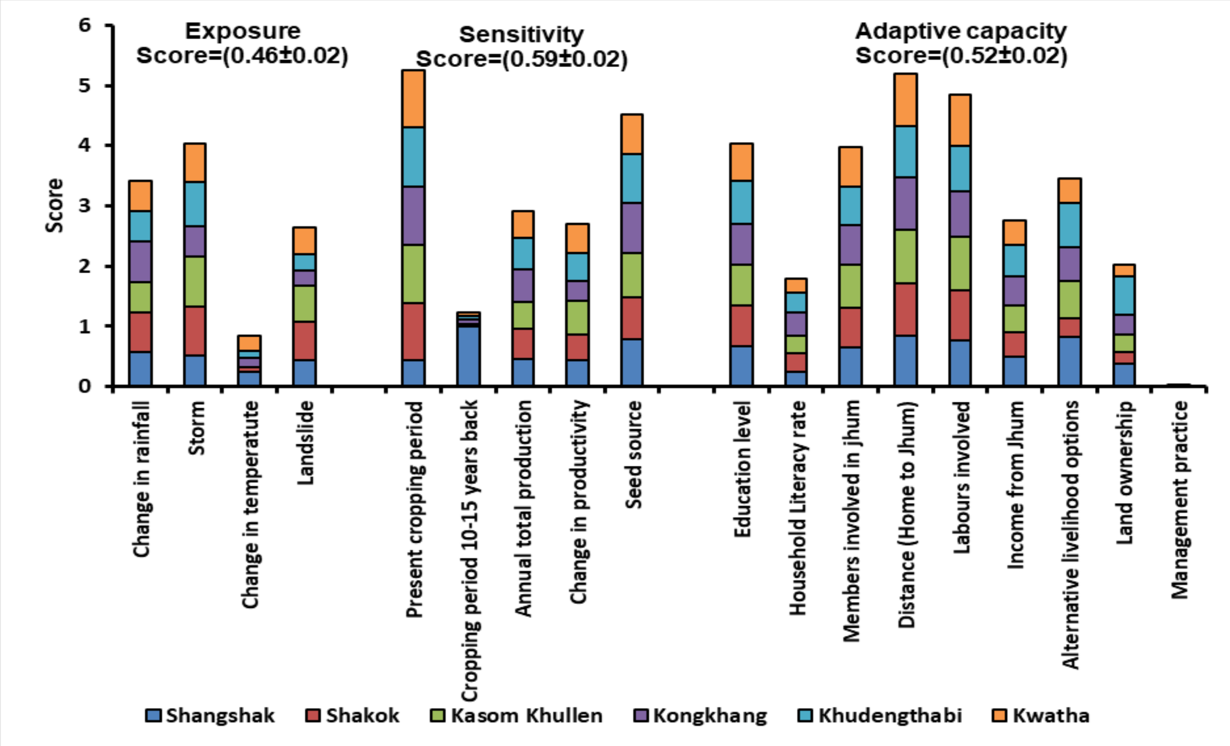


Figure 6.4: Magnitude of indicators in dimensions across villages in Manipur

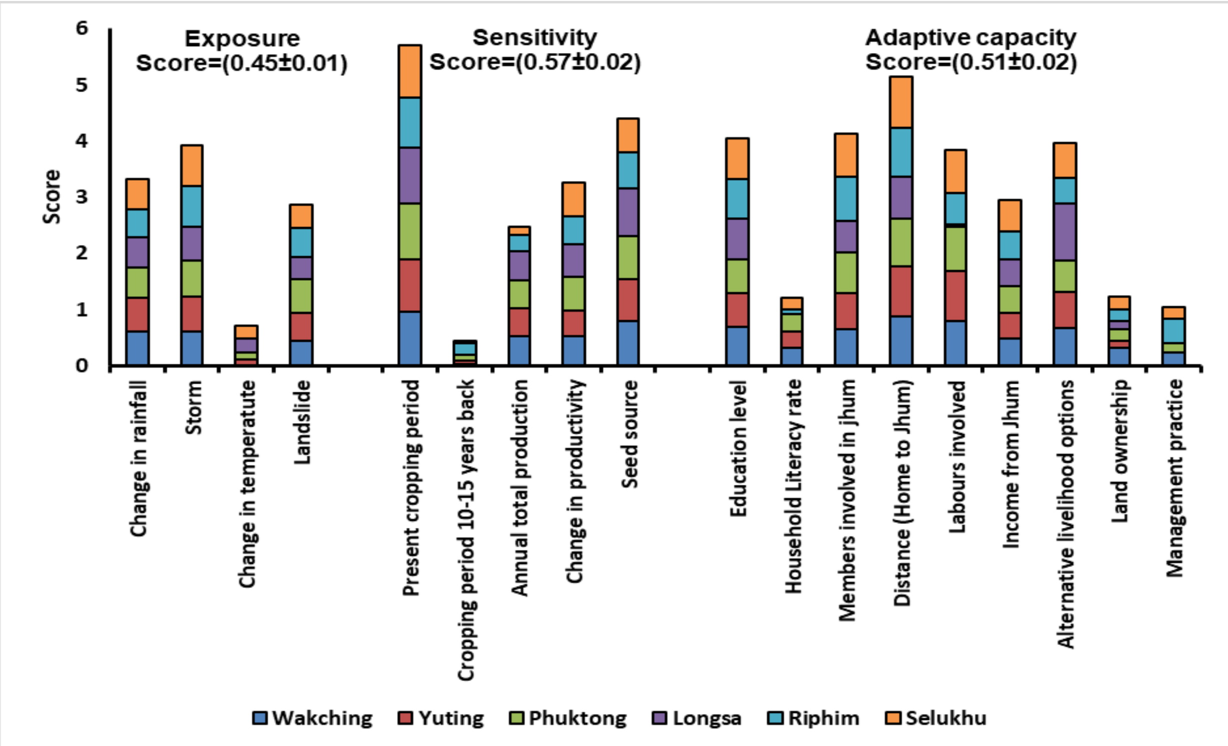


Figure 6.5: Magnitude of indicators in dimensions across villages in Nagaland

Climate related hazards namely landslides and storms, have had low to moderate impacts on both Shangshak and Kawlkulh. Survey finding indicates that in Shangshak 44% of practice jhum in communal land, 36% practice on lease land and only 20% owns a jhum land. The entire respondents in Kawlkulh practiced jhum in their own land of size not bigger than 2 acre. Jhum has been the only source of livelihood for about 76-84% of the respondents in these villages wherein only 48% of jhumias in Shangshak sold their produce and 76% in Kawlkulh. Therefore, during any event of natural hazard when the crops are destroyed, the marginal farmers are probable to face resource meagreness. Furthermore, the closest towns, Ukhrul and Khawzawl are located approximately 23 km and 35 km from Shangshak and Kawlkulh, respectively, and therefore, the daily cost of transportation from jhum to the markets are about ₹500 while the daily income is about ₹2000. Sesawng, on the other hand, have seen storms and low-level landslides. Every respondent worked exclusively in the jhum landuse type as their only source of income. For 60% of households, about 3 to 4 family members are totally invested in jhum, the size of which is >3 acre. The economic situation of the jhumias in the village was improved because almost 3/4 of the produce was sold in the closest market (Seling), which is located about 3.3 kilometres from Sesawng

6.3.4 Relation between SeVI and elevation of the villages

No significant correlation was found between elevation and SeVI for the whole studied village (N=18). However, state-wise correlation analysis found the vulnerability of the villages of Manipur to be significantly positively related to elevation ($R=0.74$, $P<0.05$), showing that an incerase in elevation corresponds to an increase in the socio-economic vulnerability.

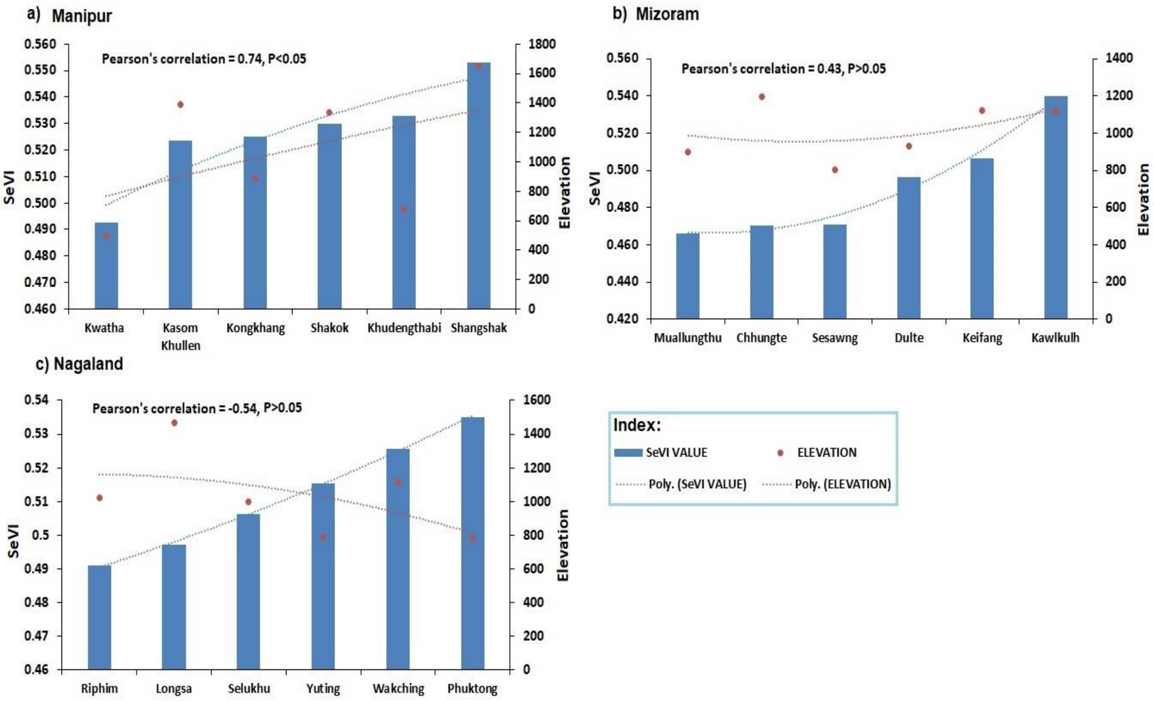


Figure 6.6: Correlation betweem SeVI and elevation of the sampled villages

6.4 Discussion

The economic outcome of climate change is progressively becoming a matter of concern for the decision makers (Brown et al., 2011). In rainfed agriculture, the increase in temperature and decrease in rainfall causes shortening of growing season and decline in crop production thereby affecting the economy of the farmers (Akram, 2012; Ashalatha et al., 2012; Sequeira et al., 2018). At such condition, the demand for atmospheric water escalates which leads to water stress from increased water pressure deficits, eventually depleting the soil moisture and minimizing the yield (Asseng et al., 2011; Zhao et al., 2016). Due to variation in access to resources, any change in climate contributes to amplify the economic disparities among the farmers. Response to heterogeneity of temperature, rainfall and crop choices leads to income drop of some farmer's while others enriches (Bécu, 2012). Therefore, to increase productivity, intensify resilience to climatic stress and promote food and income security, the Food and Agriculture Organization (FAO, 2010) of the United Nations presented the Climate-smart agriculture (CSA) approach. Broadly, CSA integrates traditional and innovative methods and technologies to adapt to the changing climate (CIAT, 2014). The extent for implication of CSA is influenced by factors namely socio-economic features of the farmer, bio-physical environment and attributes of latest technologies (Below et al., 2012). Socio-economic variables particularly the gender, age, literacy of the household head, social group, family size, land ownership, farm size, distance to the farm and slope of the farm influences the decision to adopt different CSA practices (Aryal et al., 2018).

The effectiveness, adaptability, and durability of traditional knowledge, which has been developed over centuries of trial and error, have been proven for the sustainable food production under climate change (Sugam et al. 2016). Farmers use locally accessible materials and favours local varieties over hybrids. These local crop varieties have superior resistance to unfavourable environmental circumstances and also contribute to the conservation of germplasm (Ficiciyan et al. 2018). Traditional adaptive knowledge of the jhum cultivators also include integration of trees during cropping phase to accelerate the recovery of soil fertility during the fallow period (Bhan 2009), mixed farming for crop diversification (Deb et al. 2013). Soil and water conservation measures such as zero tillage, placement of poles along the contour, mulching with weeds (Bhan 2009; Rathore et al. 2012), salt application for weed management (Rathore et al. 2012), ash/smoke application for pest and disease management (Sophia et al. 2006), etc. Therefore, under CSA, this traditional knowledge along with other modern techniques will be helpful in maintaining the food security of the populace and increase the adaptation to hazards of climate change.

For the tribal population of North-East India, jhum is not only a crop production system but in many aspects, a way of life. It has however been continuously targeted as threat to climate or environment, but its promising prospect to climate smart innovations can improve the economic status of the jhumias while achieving traditional and sustainable farming.

Chapter 7

Recovery pattern of vegetation following shifting cultivation

7.1 Introduction

Shifting cultivation is a major land use in tropics despite the fact that it is blamed to be a major cause of forest loss. Serious concerns are raised that this practice though the oldest form of agriculture may negatively affect biodiversity, carbon stocks and greenhouse gas emissions (Fearnside, 2000; Kote-Same et al., 1997). However, this practice provides subsistence livelihoods to millions of people worldwide (Brady, 1996) and, therefore, it is likely to continue as it is intricately linked to cultural, ecological and economic aspects of communities (Ramakrishnan, 1992). This practice is characterized by the alternation of the cropping and fallow phase, while the abandoned land regenerates naturally. After a certain fallow period, the trees are slashed and burnt for the ashes to enrich the soil, thus allowing a new cropping phase. This intervening period between two successive slashed and burnt practices is termed as jhum cycle. The fallow duration and cropping period are specifically influenced by ecological and socio-economic factors (Mertz, 2002). In North-East India, this practice is locally known as jhum where the cropping period has been reported to be 1–2 years with a fallow duration varying from 6–12 years (Thong et al., 2018a, 2019a). The regional estimation of abandoned land after jhum differs significantly depending on the means of estimation. However, wasteland assessment conducted during 2015-2016 showed that this region encompasses 3764.44 km2 of the National area of abandoned land (NRSC, 2019). Mizoram, Manipur and Nagaland, in particular, have 4.80% (1011.39 Km^2), 1.34% (298.65 Km^2) and 4.11% (681.21 Km^2) of its total geographical area under abandoned jhum land respectively. Under the natural process of ecological recovery, the abandoned lands are eventually restored to secondary forests.

In the tropical region, secondary forests constitute over 50% of the forested area and have the ability to assimilate and store carbon (Jepsen, 2006). In India, secondary forests cover about 32 million ha which is approximately 45.8% of the forest area of the country (Chaturvedi, 1992). The dynamic nature of shifting cultivation results in a landscape mosaic of jhum field, secondary forests and old growth forests. As such, many forests in North-East India are secondary forests at different stages of succession following shifting cultivation. These forests are an essential source of rural livelihood and also for multiple environmental functions such as soil and watershed conservation, flood control and carbon storage (Heinimann et al., 2017). However, secondary forests get constantly subjected to increasing exploitation by the growing population as well as by budding industrial and urban demand for forest products. Succession following jhum is comprised of fast growing species with high regeneration and species accumulation than other human-modified and abandoned agroforestry systems (Ferguson et al., 2001). In the tropics, the diversity of woody species steadily increases with the age of fallow (Thong et al., 2016).

Given the importance of the secondary forests and the human pressure on these resources, the present study is conducted to understand the vegetation recovery pattern following shifting cultivation and identify naturally occurring potential tree species to accelerate the restorative phase of the fallows.

7.2 Materials and methods

7.2.1 Site selection

Keeping in view the topographical parameters, soil type, and mean annual rainfall and temperature, four different fallow periods after the abandonment of the jhum fields were selected, namely, 5 (JF_5), 10 (JF_{10}), 15 (JF_{15}) and 20 (JF_{20}) years fallow (Table 7.1). The study sites were selected as per the findings of Chapter 4 and the plot was navigated using a GPS.

Table 7.1: Detailed characteristics of the study sites

State	District	Fallow age	Geographical coordinates (in Decimal Degrees)	Elevation (in m)	Slope (in °)	Aspect
Mizoram	Champhai	5	23.6628 - 23.6711 N and 93.0581 - 93.0650 E	679 - 881	12.65 - 30.94	E, NW
		5	23.5014 - 23.5050 N and 93.2208 - 93.2269 E	938 - 1109	9.23 - 26.96	S, SW
		5	23.6089 - 23.6142 N and 93.0564 - 93.0589 E	601 - 680	10.96 - 31.15	N, NW
		10	23.5897 - 23.5917 N and 93.0703 - 93.0717 E	734 - 764	8.5 - 16.59	E, SE, S, SW
		10	23.4222 - 23.4256 N and 93.2667 - 93.2678 E	919 - 1013	10.04 - 22.52	N, NE, E
		10	23.5900 - 23.5919 N and 93.1067 - 93.1133 E	725 - 790	8.67 - 24.53	SE, S
		15	23.6394 - 23.6406 N and 93.0467 - 93.0506 E	751 - 806	9.55 - 27.47	SE, S, SW
		15	23.4575 - 23.4633 N and	914 - 1029	16.41 - 28.88	N, NE, E,

			93.2525 - 93.2556 E			SE, S
		15	23.6078 - 23.6122 N and 93.0628 - 93.0639 E	634 - 662	7.94 - 20	W, NW
		20	23.6353 - 23.6375 N and 93.0572 - 93.0592 E	871 - 918	10.92 - 25.64	E, SE
		20	23.4711 - 23.4742 N and 93.2397 - 93.2411 E	971 - 1068	21.76 - 30.7	N NE
		20	23.6244 - 23.6256 N and 93.0683 - 93.0697 E	719 - 738	7.29 - 23.94	SW, W, NW
	Aizawl	5	23.7839 - 23.7847 N and 92.8500 - 92.8664 E	657 - 708	11.43 - 28.14	NE, E, W
		5	23.5753 - 23.5761 N and 92.7153 - 92.7167 E	785 - 832	8.89 - 26.56	NE, E, SE
		5	23.6758 - 23.6769 N and 92.9553 - 92.9569 E	882 - 926	11.82 - 26.53	W, NW
		10	23.7681 - 23.7689 N and 92.8536 - 92.8542 E	832 - 886	14.16 - 23.58	S, SW
		10	23.5800 - 23.5811 N and 92.7247 - 92.7261 E	722 - 785	6.47 - 23	E, SE, S, SW
		10	23.6756 - 23.6767 N and 92.9478 - 92.9494 E	733 - 777	8.68 - 25.32	SW, W, NW
		15	23.7692 - 23.7700 N and 92.8606 - 92.8614 E	732 - 790	10.84 - 25.77	NW
		15	23.6017 - 23.6036 N and 92.7222 - 92.7236 E	742 - 813	18.99 - 25.39	S, SW
		15	23.6797 - 23.6806 N and 92.9503 - 92.9514 E	700 - 733	5.89 - 18.02	SW, W
		20	23.7706 - 23.7714 N and 92.8653 - 92.8664 E	754 - 799	11.93 - 26.07	NE, E
		20	23.5644 - 23.5658 N and 92.7228 - 92.7236 E	763 - 829	14.75 - 44.2	SE, S
		20	23.6719 - 23.6733 N and 92.9483 - 92.9489 E	820 - 845	6.89 - 14.05	W, NW, N
Manipur	Ukhrul	5	24.9969 - 24.9973 N and 94.3046 - 94.3050 E	995 - 1215	0.53 - 41.2	N, SE, S, W
		5	24.8632 - 24.8636 N and 94.3044 - 94.3046 E	1036 - 1152	1.19 - 37.43	N, NE, SE, S, SW
		5	24.6766 - 24.6768 N and 94.2687 - 94.2689 E	1085 - 1285	13.28 - 42.08	S, SW, W, NW
		10	24.9842 - 24.9847 N and 94.3416 - 94.3419 E	1369 - 1537	2.87 - 32	N, E, SE, S
		10	24.8811 - 24.8818 N and 94.3134 - 94.3142 E	1179 - 1313	3.72 - 43.19	N, E, SE, SW
		10	24.6690 - 24.6698 N and 94.2859 - 94.2862 E	1190 - 1290	1.56 - 55.78	N, NE, S, NW
		15	24.9809 - 24.9811 N and 94.3202 - 94.3205 E	1256 - 1404	11.28 - 42.44	NE, E, SE
		15	24.8598 - 24.8604 N and 94.3155 - 94.3160 E	1216 - 1275	2.67 - 48.58	N, NE, E, S
		15	24.6609 - 24.6614 N and 94.2947 - 94.2953 E	1266 - 1351	1.93 - 42.33	N, E, S, W
		20	24.9764 - 24.9767 N and 94.3354 - 94.3357 E	1424 - 1491	14.88 - 34.07	SW, W, NW
		20	24.8739 - 24.8742 N and	1225 -	9.54 - 44.3	N, W, NW

			94.3060 - 94.3063 E	1330		
		20	24.6597 - 24.6604 N and 94.2770 - 94.2776 E	1242 - 1268	3.25 - 41.61	N, E, S, SW
	Chandel	5	24.3421 - 24.3424 N and 94.1901 - 94.1903 E	593 - 886	13.43 - 35.98	N, NE, E, SE, S
		5	24.3177 - 24.3180 N and 94.2510 - 94.2513 E	706 - 769	3.85 - 25.71	N, S, SW, W, NW
		5	24.3336 - 24.3339 N and 94.2734 - 94.2737 E	557 - 590	1.07 - 33.97	N, E, SE
		10	24.3519 - 24.3524 N and 94.2029 - 94.2032 E	723 - 755	2.53 - 27.14	N, E, S
		10	24.3342 - 24.3345 N and 94.2596 - 94.2594 E	398 - 441	11.43 - 30.72	E, SE, S
		10	24.3267 - 24.3271 N and 94.2736 - 94.2740 E	466 - 566	6.08 - 28.79	N, E, SE, S
		15	24.3414 - 24.3417 N and 94.2027 - 94.2030 E	507 - 650	13.79 - 37.9	SE, S, SW
		15	24.3188 - 24.3191 N and 94.2536 - 94.2540 E	645 - 708	14.62 - 32.62	NE, E, SE, S
		15	24.3146 - 24.3149 N and 94.2669 - 94.2673 E	408 - 421	3.79 - 26.76	N, E, S, W
		20	24.3648 - 24.3651 N and 94.1783 - 94.1787 E	1142 - 1247	13.94 - 24.89	NE
		20	24.3137 - 24.3141 N and 94.2469 - 94.2473 E	678 - 726	9.87 - 30.39	S, SW, W, NW
		20	24.3324 - 24.3329 N and 94.2746 - 94.2749 E	504 - 552	17.48 - 30.09	E, SE
Nagaland	Mon	5	26.7114 - 26.7119 N and 94.9056 - 94.9061 E	1033 -1073	17.51 - 31.80	SE
		5	26.6519 - 26.6525 N and 94.9792 - 94.9803 E	769 -803	17.56 - 25.13	NE, E, SE
		5	26.7942 - 26.7947 N and 95.0722 - 95.0736 E	707 - 718	12.35 - 24.91	S, SW
		10	26.7067 - 26.7069 N and 94.9064 - 94.9069 E	1045 - 1055	13.39 - 20.42	S
		10	26.6906 - 26.6911 N and 95.0150 - 95.0164 E	982 - 1028	14.04 - 24.85	SW, W
		10	26.7667 - 26.7678 N and 95.0622 - 95.0633 E	964 - 988	12.22 - 24	SW, S
		15	26.7169 - 26.7175 N and 94.9189 - 94.9197 E	833 - 864	9.12 - 23.03	E
		15	26.6831 - 26.6833 N and 95.0183 - 95.0189 E	978 - 1035	16.53 - 28.48	NW, N
		15	26.7811 - 26.7828 N and 95.0722 - 95.0733 E	910 - 970	14.52 - 33.68	NE, E, NW, N
		20	26.7186 - 26.7189 N and 94.9219 - 94.9225 E	827 - 839	13.62 - 19.43	E, SE
		20	26.6694 - 26.6700 N and 94.9983 - 94.9994 E	1044 - 1072	13.55 - 26.47	N, NE
		20	26.7767 - 26.7775 N and 95.0686 - 95.0692 E	963 - 996	20.76 - 38.25	SW, W
	Wokha	5	26.0250 - 26.0261 N and 94.2544 - 94.2553 E	1356 - 1398	5.17 - 31.27	NE, E, SE
		5	26.1242 - 26.1269 N and	1113 -	19.07 - 39.16	SE, S

			94.2339 - 94.2367 E	1225		
		5	26.1292 - 26.1306 N and 94.3078 - 94.3092 E	1094 - 1143	13.39 - 20.95	NE, E, SE, NW
		10	26.0244 - 26.0253 N and 94.2606 - 94.2611 E	1242 - 1274	17.52 - 27.36	E, SE
		10	26.1644 - 26.1669 N and 94.2344 - 94.2361 E	530 - 591	17.11 - 28.65	S, W
		10	26.1175 - 26.1183 N and 94.3175 - 94.3192 E	1118 - 1165	18.93 - 30.06	W, NW
		15	26.0167 - 26.0178 N and 94.2533 - 94.2539 E	1293 - 1312	5.64 - 30.09	N, NE, E
		15	26.1544 - 26.1553 N and 94.2375 - 94.2397 E	931 - 1017	21.69 - 30.81	E, SE
		15	26.1172 - 26.1181 N and 94.3122 - 94.3128 E	1129 - 1166	26.86 - 35.22	W, NW
		20	26.0100 - 26.0108 N and 94.2553 - 94.2564 E	1152 - 1175	7.24 - 12.81	NE, E, NW
		20	26.1450 - 26.1481 N and 94.2600 - 94.2633 E	830 - 925	10.01 - 28.29	N, NE
		20	26.1239 - 26.1244 N and 94.3208 - 94.3225 E	998 - 1037	6.95 - 21.93	NE, E

7.2.2 Vegetation sampling

The vegetation sampling was conducted during the dry months of January and February for fallow aged 5 (JF_5), 10 (JF_{10}), 15 (JF_{15}) and 20 (JF_{20}) years. A total of 12 sites (four fallow aged plots x three replicates) were identified in each district (Figure 7.1). At each site, five quadrates of 10 m x 10 m were randomly laid for identifying tree species at different stages of their growth, namely trees, pole, saplings and seedlings. The diameter at breast height (dbh) was measured at 1.37 m from the ground level for individuals with dbh >3 cm. Mature trees were defined as stems with dbh ≥10 cm and height >2 m, poles as individuals with dbh ≥3 to <10 cm and height >2m, saplings as individuals with collar diameter <3cm and height >30 cm to ≤2 m, and seedlings as individuals with collar diameter <3cm and height upto 30 cm. The herbaria at Mizoram University and other published literatures were consulted for correct tree species identification for those which could not be identified in the field. The Plant List (www. theplantlist.org) was referred for species nomenclature classification.

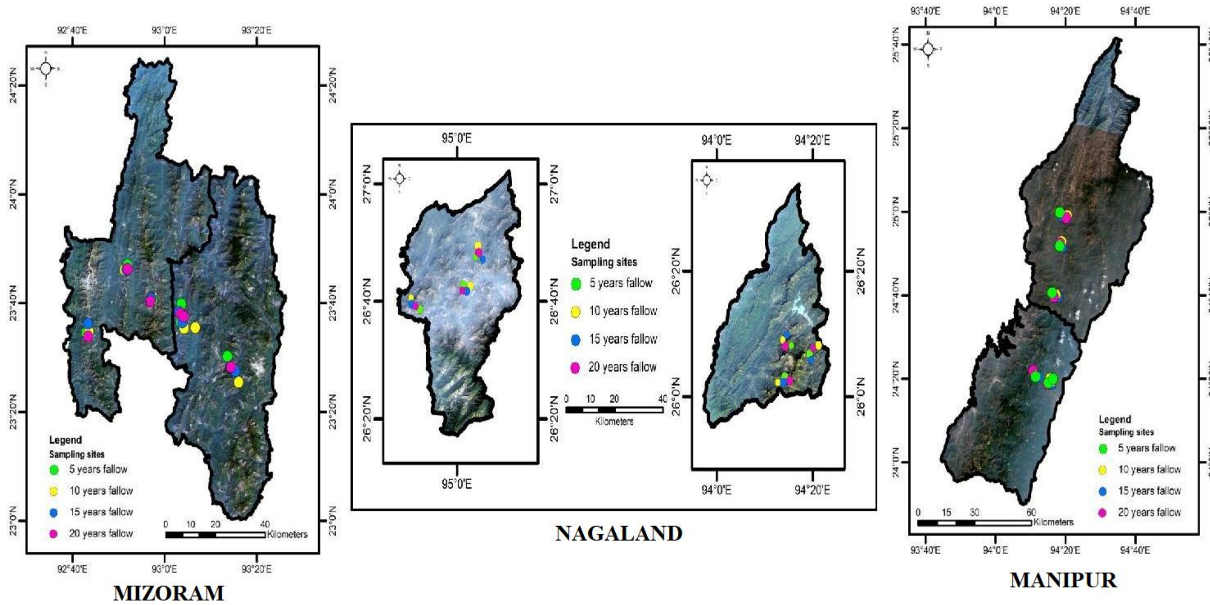


Figure 7.1: Map showing the location of the study sites (vegetation sampling)

7.2.3 Analysis of plant diversity and community structure

Community structure variables such as density, frequency, abundance and basal area in different fallow sites were calculated according to Mueller-Dombois and Ellenberg (1974). Plant diversity measures such as Shannon-Wiener diversity index (H'), Simpson's dominance index (C), and Margalef species richness index (Dmg) were also determined (Shannon and Weaver, 1949; Simpson, 1949; Margalef, 1968).

$H' = -\Sigma\ p_i \ln p_i$ where pi is the proportional abundance of species (i.e., number of species divided by total number in the community)

$C = \Sigma\ p_i^2$ where pi is same for Shannon's index

$Dmg = (S-1)/ \ln N$ where N is the total number of individuals in the sample and S is the number of species recorded

7.3 Statistical analysis

All statistical analysis was conducted using SPSS version 20.0 and PAST version 3.25. One-way ANOVA was used to examine if species richness of adult trees, poles, tree saplings, tree seedlings, shrubs and herbs (dependent variables) differed among fallow periods (fixed variable). Tukey's HSD post-hoc test was used to examine if response variables differed significantly between individual fallow period. The constrained ordination technique of Canonical Correspondence Analysis (CCA) was used to assess the environmental variables contributing to the variation in species composition among fallows. The environmental variables used in CCA were (i) elevation (ii) fallow age (iii) slope, and (iv) aspect.

To assess species richness along an increasing fallow gradient, we constructed a linear mixed-effect model (LMEM) with fallow age, slope, aspect and elevation as fixed effects, and incorporated sites nested within fallow ages as random intercepts in the model. Weights were assigned to each model interaction using the Akaike Information Criterion corrected (AICCc) and model with highest weight was selected as the best fit.

7.4 Results

7.4.1 Phytosociological and diversity attributes in fallow stands

A total of 88 tree species belonging to 32 families, 49 shrub species belonging to 22 families and 52 herb species from 30 families were recorded from fallow stands in Mizoram. In Manipur, a sum of 79 tree species from 34 families, 46 shrub species belonging to 18 families and 72 herb species belonging to 3 families were recorded from the fallow stands. In addition, a total of 76 tree species belonging to 30 families, 49 shrub species from 22 families and 45 herb species belonging to 21 families were recorded from the fallow stands in Nagaland.

Phytosociological analysis showed high tree diversity and species richness while the low values of dominance index revealed inequitable distribution of trees across increasing fallow age in the study area (Table 7.2, 7.3, 7.4).

7.4.2 Species richness in Mizoram

One-way ANOVA showed that the species richness of adult trees ($F_{3,15}$=372.31, P<0.001) increases with increasing fallow gradient in Champhai while species richness in poles ($F_{3,15}$=31.77, P<0.001) decline following 10 years fallow. Tree saplings ($F_{3,15}$=81.03, P<0.001) and tree seedlings ($F_{3,15}$=38.36, P<0.001) richness decline following 5 years fallow.

Table 7.2: Phytosociological and diversity attributes of vegetation in different jhum fallow stands in Mizoram

Attributes	**CHAMPHAI**				**AIZAWL**			
	JF_5	JF_{10}	JF_{15}	JF_{20}	JF_5	JF_{10}	JF_{15}	JF_{20}
Tree								
No. of species	37	41	44	49	31	33	38	47
No. of families	23	19	18	24	19	19	16	22
Density (individuals/ha)	1367 ± 0.57	1853 ± 0.29	2327 ± 0.43	2833 ± 0.43	1287 ± 0.47	1760 ± 0.36	2207 ± 0.41	2640 ± 0.34
Basal area (m2ha-1)	1.16 ± 0.17	9.15 ± 0.36	26.54 ± 0.99	69.54 ± 2.29	1.06 ± 0.13	7.23 ± 0.40	25.39 ± 0.89	61.42 ± 1.81
Shannon Diversity Index (H´)	1.83 ± 0.05	1.88 ± 0.04	1.98 ± 0.05	2.03 ± 0.03	1.12 ± 0.06	1.76 ± 0.04	1.83 ± 0.04	1.93 ± 0.04
Simpson Dominance Index (C)	0.18 ± 0.01	0.18 ± 0.01	0.17 ± 0.01	0.16 ± 0.01	0.38 ± 0.03	0.20 ± 0.01	0.19 ± 0.01	0.17 ± 0.01
Margalef Species Richness Index (Dmg)	2.35 ± 0.12	2.33 ± 0.07	2.59 ± 0.10	2.65 ± 0.06	1.05 ± 0.06	2.05 ± 0.07	2.24 ± 0.07	2.28 ± 0.09
Shrub								
No. of species	24	22	21	24	20	26	28	25
No. of families	18	16	17	17	19	14	16	14
Density (individuals/ha)	14550 ± 0.85	12487 ± 0.77	10847 ± 0.48	9788 ± 0.36	12011 ± 0.56	11587 ± 0.44	10318 ± 0.24	9206 ± 0.27
Shannon Diversity Index (H´)	1.33 ± 0.15	1.48 ± 0.05	1.50 ± 0.06	1.37 ± 0.06	1.24 ± 0.11	1.31 ± 0.10	1.64 ± 0.05	1.50 ± 0.04
Simpson Dominance Index (C)	0.37 ± 0.07	0.25 ± 0.01	0.25 ± 0.02	0.29 ± 0.02	0.35 ± 0.05	0.33 ± 0.04	0.21 ± 0.01	0.25 ± 0.01
Margalef Species Richness Index (Dmg)	1.56 ± 0.19	1.67 ± 0.07	1.80 ± 0.10	1.63 ± 0.10	1.29 ± 0.12	1.46 ± 0.13	2.11 ± 0.09	1.92 ± 0.07
Herb								
No. of species	34	30	30	27	35	34	31	26
No. of families	24	21	19	22	27	21	21	18
Density (individuals/ha)	114333 ± 0.72	98000 ± 0.54	89000 ± 0.41	86667 ± 0.37	108333 ± 0.58	101333 ± 0.53	91667 ± 0.39	84667 ± 0.35
Shannon Diversity Index (H´)	1.55 ± 0.07	1.34 ± 0.12	1.53 ± 0.06	1.55 ± 0.05	1.64 ± 0.07	1.67 ± 0.07	1.59 ± 0.05	1.60 ± 0.04
Simpson Dominance Index (C)	0.25 ± 0.02	0.35 ± 0.05	0.25 ± 0.02	0.23 ± 0.01	0.23 ± 0.02	0.22 ± 0.02	0.22 ± 0.01	0.22 ± 0.01
Margalef Species Richness Index (Dmg)	1.85 ± 0.11	1.66 ± 0.15	1.93 ± 0.10	1.93 ± 0.08	2.09 ± 0.10	2.17 ± 0.11	1.98 ± 0.08	2.08 ± 0.07

Table 7.3: Phytosociological and diversity attributes of vegetation in different jhum fallow stands in Manipur

Attributes	UKHRUL				CHANDEL			
	JF_5	JF_{10}	JF_{15}	JF_{20}	JF_5	JF_{10}	JF_{15}	JF_{20}
Tree								
No. of species	21	30	34	34	25	26	29	31
No. of families	15	18	20	21	20	16	22	20
Density (individuals/ha)	1233 ± 0.41	1900 ± 0.76	2287 ± 0.88	2693 ± 0.73	1493 ± 0.40	2020 ± 0.31	2527 ± 0.66	2993 ± 0.60
Basal area (m2ha-1)	0.85 ± 0.18	9.1 ± 0.48	29.26 ± 1.59	67.92 ± 2.86	1.22 ± 0.12	7.97 ± 0.33	32.10 ± 1.19	72.93 ± 3.98
Shannon Diversity Index (H´)	1.72 ± 0.07	1.97 ± 0.11	1.84 ± 0.14	2.28 ± 0.09	1.61 ± 0.11	1.83 ± 0.08	1.88 ± 0.15	2.44 ± 0.11
Simpson Dominance Index (C)	0.21 ± 0.02	0.18 ± 0.03	0.23 ± 0.04	0.13 ± 0.01	0.25 ± 0.03	0.19 ± 0.02	0.22 ± 0.04	0.11 ± 0.01
Margalef Species Richness Index (Dmg)	2.24 ± 0.16	2.81 ± 0.30	2.52 ± 0.31	3.48 ± 0.29	1.96 ± 0.24	2.13 ± 0.19	2.43 ± 0.28	3.70 ± 0.46
Shrub								
No. of species	21	19	19	16	20	21	18	18
No. of families	12	10	9	9	12	11	10	9
Density (individuals/ha)	13439 ± 0.80	12698 ± 0.69	11587 ± 0.47	10000 ± 0.33	12328 ± 0.40	11746 ± 0.40	10370 ± 0.26	9206 ± 0.24
Shannon Diversity Index (H´)	1.51 ± 0.06	1.59 ± 0.05	1.60 ± 0.05	1.45 ± 0.08	1.55 ± 0.03	1.65 ± 0.06	1.55 ± 0.04	1.44 ± 0.05
Simpson Dominance Index (C)	0.24 ± 0.02	0.22 ± 0.01	0.22 ± 0.01	0.27 ± 0.04	0.23 ± 0.01	0.22 ± 0.02	0.23 ± 0.01	0.26 ± 0.01
Margalef Species Richness Index (Dmg)	1.64 ± 0.09	1.78 ± 0.07	1.87 ± 0.08	1.69 ± 0.11	1.71 ± 0.07	2.03 ± 0.09	1.88 ± 0.08	1.73 ± 0.08
Herb								
No. of species	31	29	24	21	33	30	28	23
No. of families	20	19	16	12	21	21	19	14
Density (individuals/ha)	111000 ± 0.69	104000 ± 0.54	90667 ± 0.36	88667 ± 0.36	113333 ± 0.70	99667 ± 0.53	89667 ± 0.41	90000 ± 0.39
Shannon Diversity Index (H´)	1.39 ± 0.12	1.42 ± 0.09	1.37 ± 0.04	1.28 ± 0.06	1.64 ± 0.06	1.48 ± 0.08	1.45 ± 0.08	1.45 ± 0.06
Simpson Dominance Index (C)	0.33 ± 0.05	0.29 ± 0.04	0.27 ± 0.01	0.31 ± 0.02	0.21 ± 0.01	0.28 ± 0.04	0.28 ± 0.03	0.26 ± 0.02
Margalef Species Richness Index (Dmg)	1.59 ± 0.15	1.54 ± 0.10	1.45 ± 0.06	1.41 ± 0.08	1.96 ± 0.10	1.77 ± 0.11	1.76 ± 0.11	1.73 ± 0.09

Table 7.4: Phytosociological and diversity attributes of vegetation in different jhum fallow stands in Nagaland

Attributes	**MON**				WOKHA			
	JF_5	JF_{10}	JF_{15}	JF_{20}	JF_5	JF_{10}	JF_{15}	JF_{20}
Tree								
No. of species	20	27	34	35	24	29	39	36
No. of families	14	16	21	22	19	16	24	20
Density (individuals/ha)	1047 ± 0.49	1473 ± 0.54	1920 ± 0.51	2107 ± 0.74	1240 ± 0.34	1633 ± 0.21	1900 ± 0.68	2160 ± 0.52
Basal area (m2ha-1)	0.95 ± 0.15	6.13 ± 0.33	20.71 ± 0.98	46.91 ± 1.87	1.18 ± 0.15	8.03 ± 0.47	22.07 ± 1.02	50.95 ± 2.17
Shannon Diversity Index (H´)	1.79 ± 0.07	2.14 ± 0.04	2.33 ± 0.04	2.28 ± 0.05	1.83 ± 0.04	2.24 ± 0.03	2.30 ± 0.06	2.34 ± 0.04
Simpson Dominance Index (C)	0.19 ± 0.01	0.13 ± 0.01	0.11 ± 0.005	0.11 ± 0.01	0.17 ± 0.01	0.11 ± 0.003	0.11 ± 0.01	0.11 ± 0.01
Margalef Species Richness Index (Dmg)	2.40 ± 0.14	3.09 ± 0.11	3.54 ± 0.12	3.19 ± 0.13	2.33 ± 0.10	3.27 ± 0.08	3.47 ± 0.17	3.45 ± 0.10
Shrub								
No. of species	17	21	21	14	19	21	22	18
No. of families	10	17	14	7	12	13	16	9
Density (individuals/ha)	11799 ± 0.56	11164 ± 0.36	11852 ± 0.41	9206 ± 0.24	11534 ± 0.30	12646 ± 0.26	11534 ± 0.30	9947 ± 0.19
Shannon Diversity Index (H´)	1.60 ± 0.08	1.38 ± 0.13	1.44 ± 0.09	1.40 ± 0.05	1.69 ± 0.03	1.44 ± 0.08	1.42 ± 0.08	1.49 ± 0.04
Simpson Dominance Index (C)	0.23 ± 0.02	0.34 ± 0.06	0.29 ± 0.04	0.27 ± 0.02	0.20 ± 0.01	0.27 ± 0.03	0.28 ± 0.03	0.25 ± 0.01
Margalef Species Richness Index (Dmg)	1.96 ± 0.14	1.72 ± 0.18	1.70 ± 0.13	1.67 ± 0.09	2.10 ± 0.05	1.58 ± 0.12	1.62 ± 0.12	1.78 ± 0.08
Herb								
No. of species	19	18	17	15	19	21	20	16
No. of families	10	11	9	10	12	13	11	9
Density (individuals/ha)	97667 ± 0.38	92333 ± 0.39	83667 ± 0.28	79000 ± 0.25	101333 ± 0.32	96000 ± 0.38	86000 ± 0.30	82333 ± 0.26
Shannon Diversity Index (H´)	1.35 ± 0.07	1.32 ± 0.07	1.16 ± 0.07	1.23 ± 0.08	1.47 ± 0.06	1.38 ± 0.06	1.35 ± 0.05	1.41 ± 0.05
Simpson Dominance Index (C)	0.31 ± 0.03	0.31 ± 0.03	0.37 ± 0.03	0.34 ± 0.04	0.26 ± 0.03	0.29 ± 0.02	0.29 ± 0.02	0.27 ± 0.02
Margalef Species Richness Index (Dmg)	1.55 ± 0.11	1.48 ± 0.09	1.29 ± 0.09	1.43 ± 0.10	1.69 ± 0.08	1.57 ± 0.09	1.58 ± 0.08	1.69 ± 0.08

In addition, Tukey's test showed that species richness differ among fallows of various ages with highest difference in adult trees (Figure 7.2). Species richness of shrubs ($F_{3,15}$=0.33, P=0.805) and herbs ($F_{3,15}$=1.42, P=0.248) did not show any significant difference with increasing fallow age.

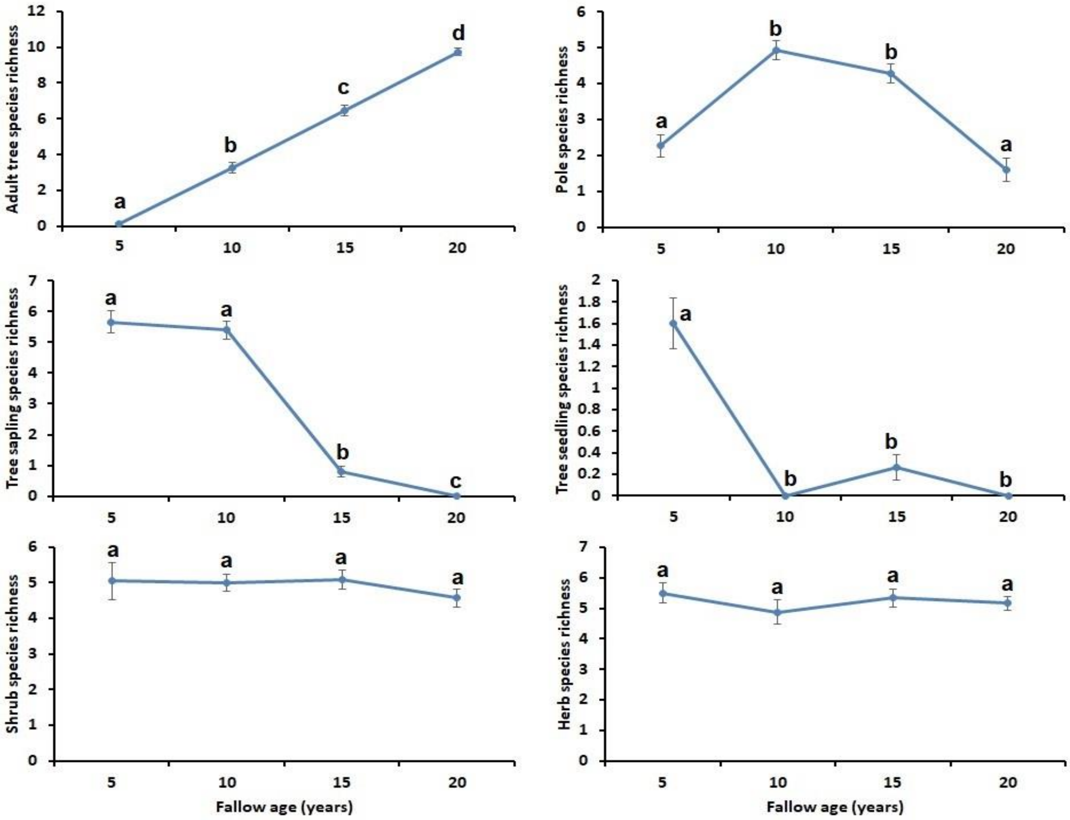


Figure 7.2: Species richness of adult trees, poles, tree saplings, tree seedlings, shrubs and herbs in different fallow age in Champhai. Error bars are standard error. Bars do not share a letter differ significantly (Tukey's hsd, P < 0.05)

In Aizawl as well, the species richness of adult trees ($F_{3,15}$=241.11, P<0.001) increases with increasing fallow gradient while species richness of poles ($F_{3,15}$=23.74, P<0.001) and tree saplings ($F_{3,15}$=113.14, P<0.001) decline following 10 years fallow. Species richness of tree seedlings ($F_{3,15}$=10.54, P<0.001) and shrubs ($F_{3,15}$=5.48, P<0.01) decline after 5 years and 15 fallow respectively. Tukey's test showed that species richness differ among fallows of various ages with highest difference in adult trees and tree saplings. Species richness of herbs ($F_{3,15}$=0.48, P=0.698) did not show any significant difference with increasing fallow age (Figure 7.3).

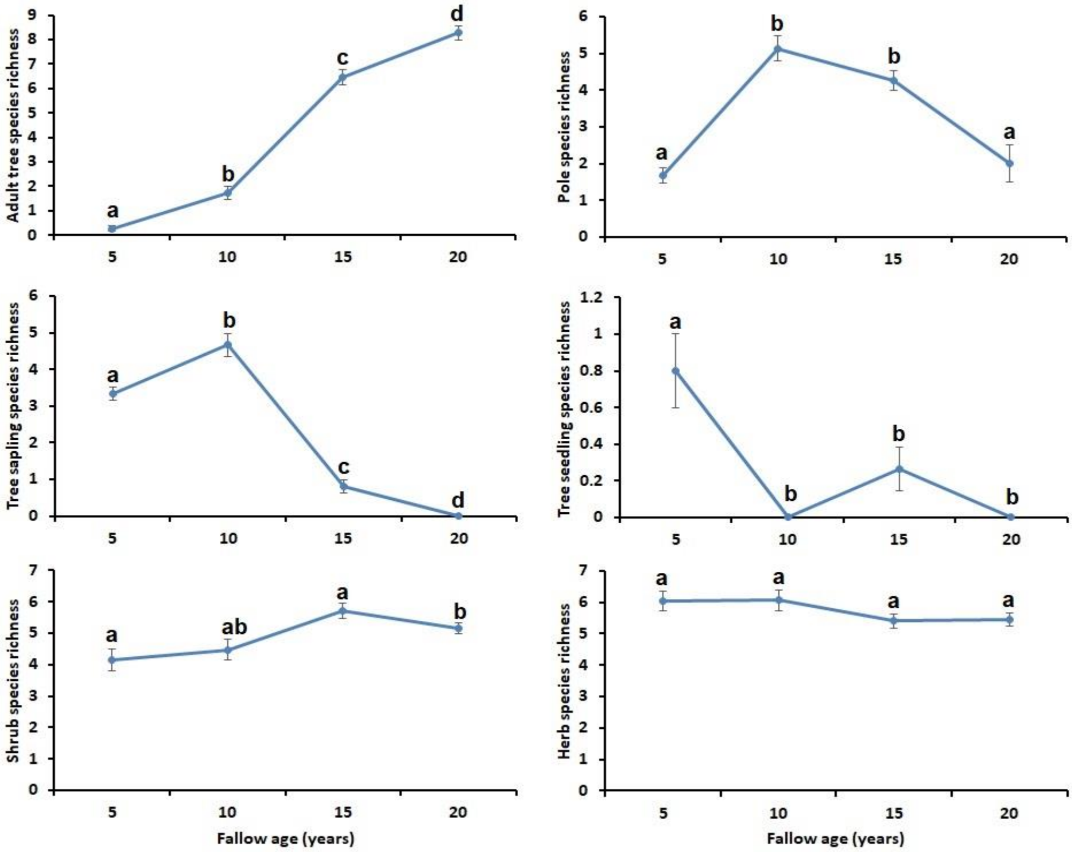


Figure 7.3: Species richness of adult trees, poles, tree saplings, tree seedlings, shrubs and herbs in different fallow age in Aizawl. Error bars are standard error. Bars do not share a letter differ significantly (Tukey's hsd, P < 0.05)

7.4.3 Species richness in Manipur

In Ukhrul, the species richness of adult trees ($F_{3,15}$=72.22, P<0.001) increases with fallow age while species richness of poles ($F_{3,15}$=26.42, P<0.001) and tree saplings ($F_{3,15}$=88.88, P<0.001) decline following 10 years fallow. Species richness of tree seedlings ($F_{3,15}$=8.31, P<0.001) decline after 5 years. Tukey's test showed that species richness differ among fallows of various ages with highest difference in adult trees and poles. Species richness of shrubs ($F_{3,15}$=0.40, P=0.989) and herbs ($F_{3,15}$=0.34, P=0.797) did not show any significant difference with increasing fallow age (Figure 7.4).

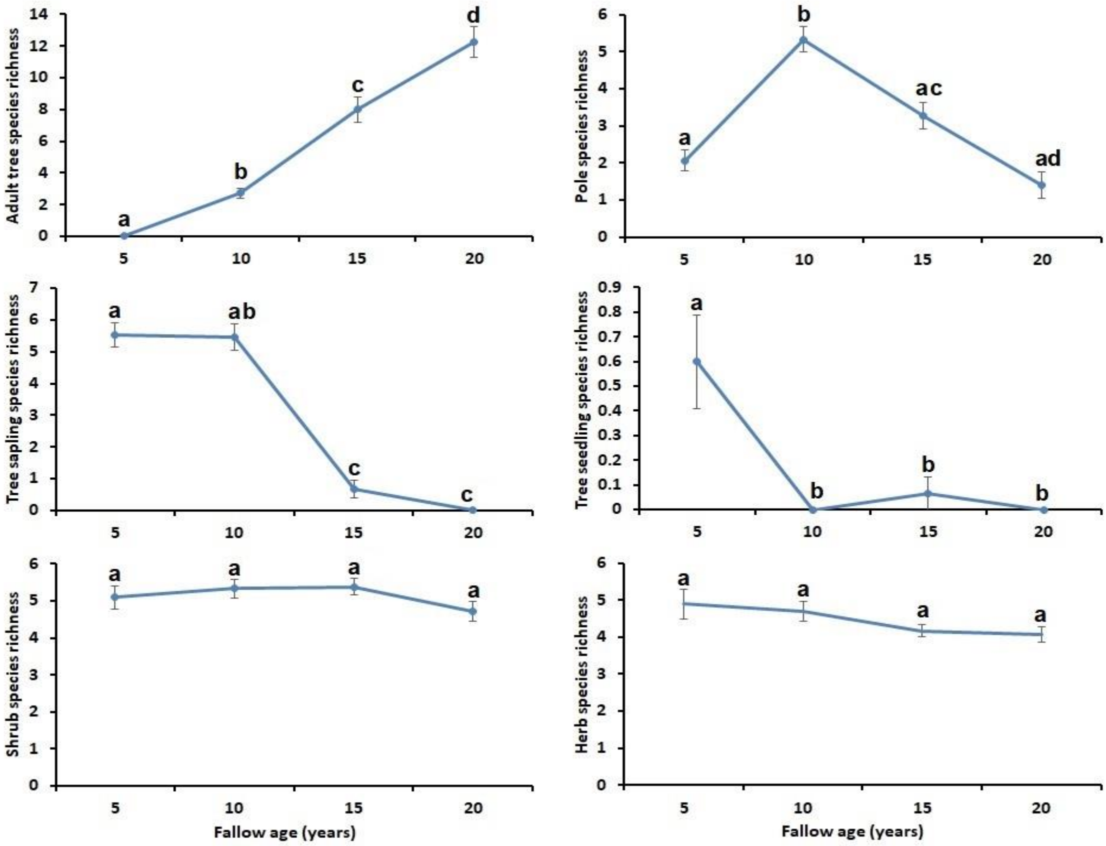


Figure 7.4: Species richness of adult trees, poles, tree saplings, tree seedlings, shrubs and herbs in different fallow age in Ukhrul. Error bars are standard error. Bars do not share a letter differ significantly (Tukey's hsd, $P < 0.05$)

The species richness of adult trees ($F_{3,15}$=45.70, P<0.001) increases with increasing fallow gradient in Chandel while species richness in poles ($F_{3,15}$=12.52, P<0.001) decline following 10 years fallow. Tree saplings ($F_{3,15}$=68.26, P<0.001) and tree seedlings ($F_{3,15}$=9.56, P<0.001) richness decline following 5 years fallow. Tukey's test did not show much difference in species richness among fallows of various ages, however highest difference was observed in adult trees. Species richness of shrubs ($F_{3,15}$=0.83, P=0.485) and herbs ($F_{3,15}$=1.11, P=0.351) did not show any significant difference with increasing fallow age (Figure 7.5).

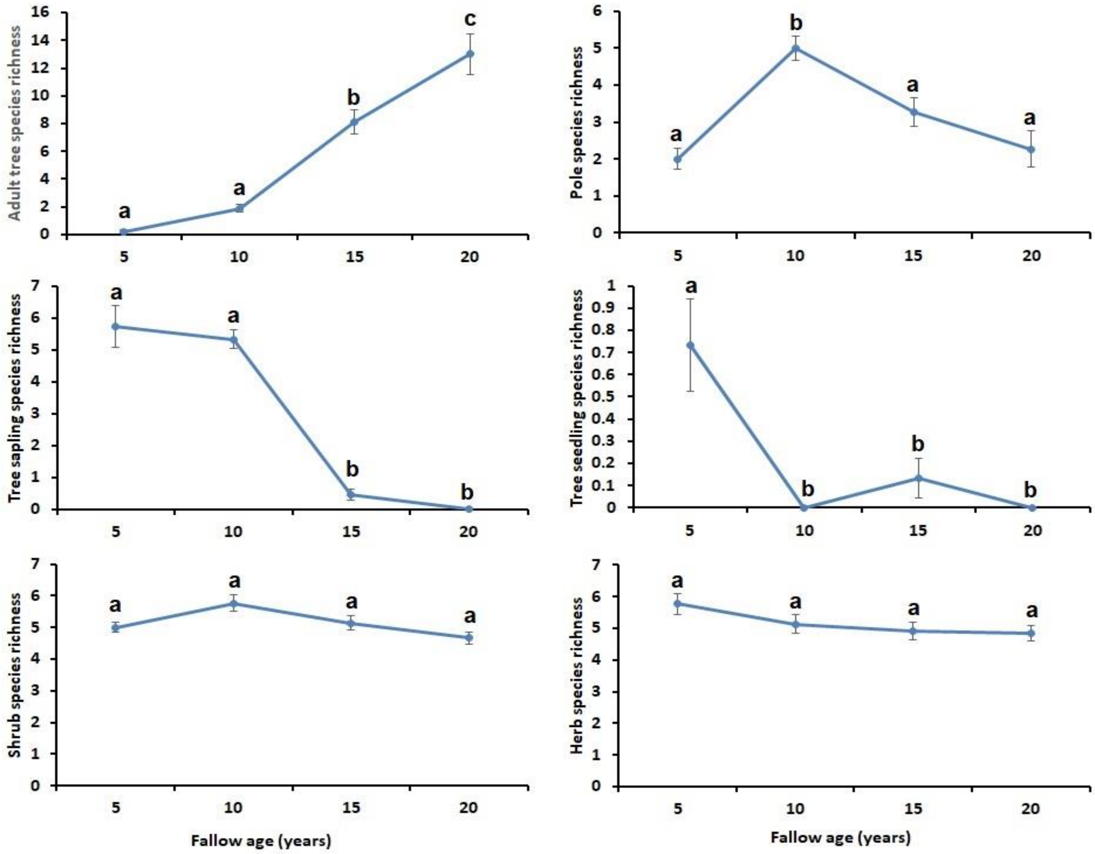


Figure 7.5: Species richness of adult trees, poles, tree saplings, tree seedlings, shrubs and herbs in different fallow age in Chandel. Error bars are standard error. Bars do not share a letter differ significantly (Tukey's hsd, P < 0.05)

7.4.4 Species richness in Nagaland

In Mon, the species richness of adult trees ($F_{3,15}$=184.84, P<0.001) increases with increasing fallow gradient in Chandel while species richness in poles ($F_{3,15}$=35.51, P<0.001) decline following 15 years fallow. Tree saplings ($F_{3,15}$=79.55, P<0.001) and tree seedlings ($F_{3,15}$=14.76, P<0.001) richness decline after 10 years and 5 years fallow respectively. Tukey's test did not show much difference in species richness among fallows of various ages, however highest difference was observed in adult trees. Species richness of shrubs ($F_{3,15}$=0.92, P=0.438) and herbs ($F_{3,15}$=1.10, P=0.356) did not show any significant difference with increasing fallow age (Figure 7.6).

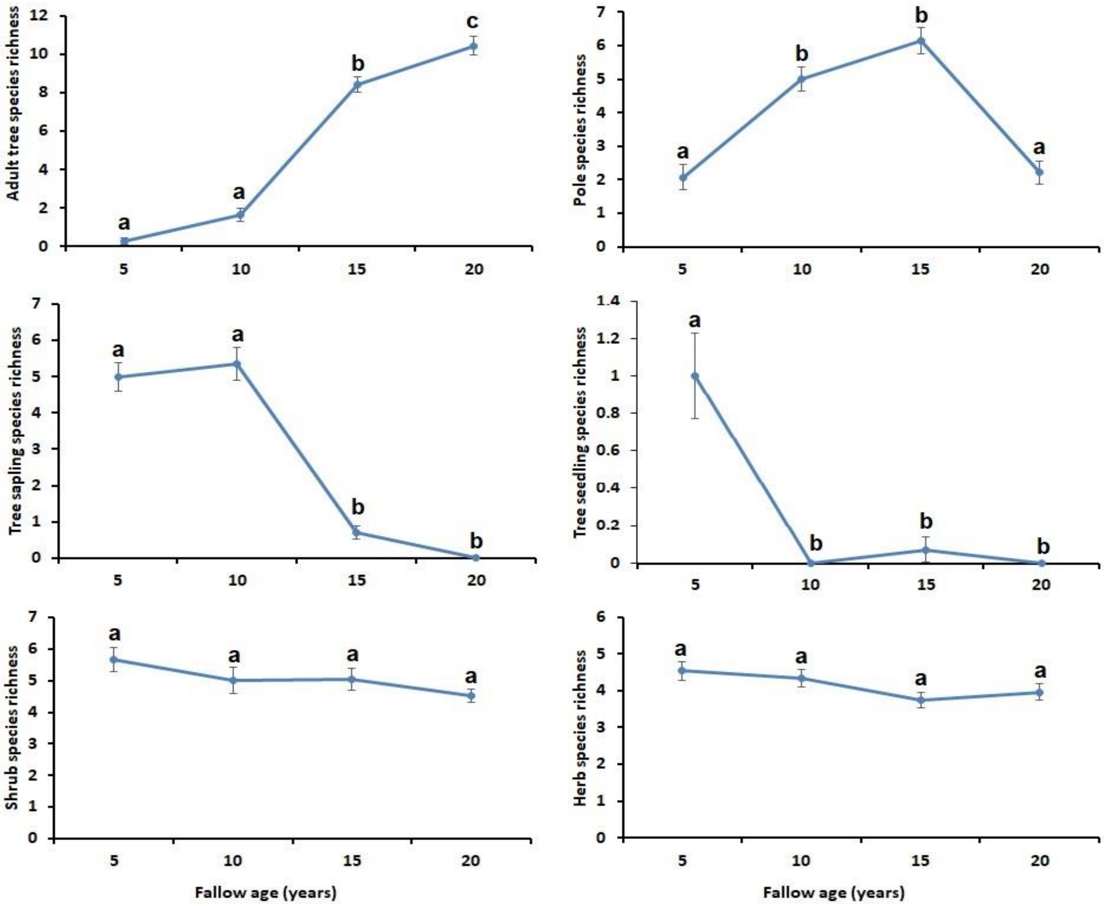


Figure 7.6: Species richness of adult trees, poles, tree saplings, tree seedlings, shrubs and herbs in different fallow age in Mon. Error bars are standard error. Bars do not share a letter differ significantly (Tukey's hsd, $P < 0.05$)

In Wokha as well, the species richness of adult trees ($F_{3,15}$=111.31, P<0.001) increases with increasing fallow gradient while species richness of poles ($F_{3,15}$=12.62, P<0.001) and tree saplings ($F_{3,15}$=75.53, P<0.001) decline following 10 years fallow. Species richness of tree seedlings ($F_{3,15}$=10.54, P<0.001) decline after 5 years. Tukey's test did not show much difference in species richness among fallows of various ages, however highest difference was observed in adult trees. Species richness of shrubs ($F_{3,15}$=2.29, P=0.088) and herbs ($F_{3,15}$=0.99, P=0.406) did not show any significant difference with increasing fallow age (Figure 7.7).

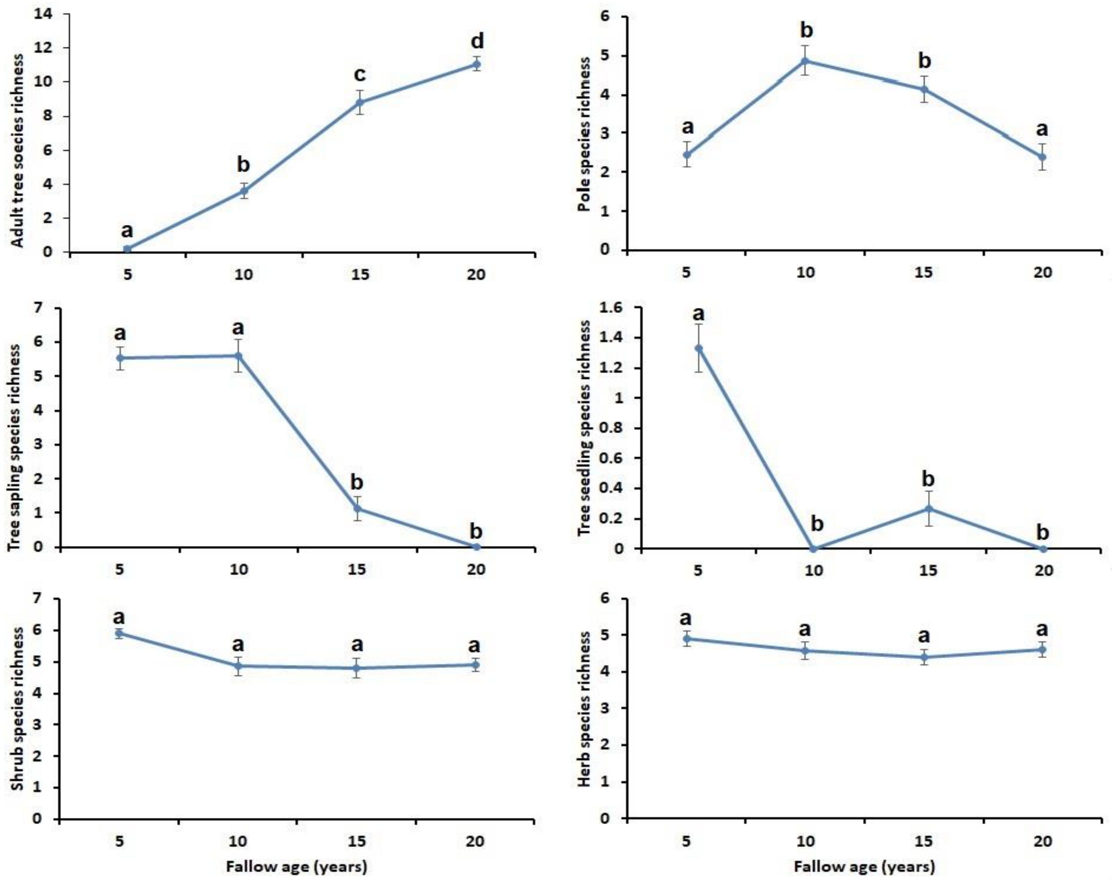


Figure 7.7: Species richness of adult trees, poles, tree saplings, tree seedlings, shrubs and herbs in different fallow age in Wokha. Error bars are standard error. Bars do not share a letter differ significantly (Tukey's hsd, $P < 0.05$)

7.4.5 Factors affecting the species richness along an increasing fallow gradient

The fallow age and elevation was found to have contributed the most to the tree and herb species richness in Champhai while fallow age contributed the most to shrub's species richness (Table 7.5). It was observed that slope also contributes to overall species richness. In addition, elevation and aspect contributes to shrub and herb species richness respectively. In Aizawl, the fallow age was found to have contributed the most to tree, shrub and herb species richness. Besides, elevation, slope and aspect also contributed to overall species richness

Table 7.5: Summary of LMEM across site's species richness with environmental variables in Mizoram

CHAMPHAI									
Parameter	Explanatory variables				Log Likelihood	AIC	AICc	Δ AICc	Weight
	Fallow	Slope	Aspect	Elevation					
Tree species richness	X			X	160.94	180.94	185.43	0	0.803
	X				174.87	186.87	188.45	3.02	0.177
	X	X		X	156.07	184.07	193.4	7.97	0.015
	X	X			171.07	191.07	195.56	10.13	0.005
Shrub species richness	X				308.65	320.65	321.74	0	0.894
	X	X			304.23	324.23	327.24	5.5	0.057
	X			X	304.72	324.72	327.73	5.99	0.045
Herb species richness	X			X	455.99	475.99	478.01	0	0.775
	X				468.24	480.24	480.98	2.97	0.176
	X		X		452.55	480.55	484.55	6.54	0.029
	X	X		X	454.7	482.7	486.7	8.69	0.010
AIZAWL									
Parameter	Explanatory variables				Log Likelihood	AIC	AICc	Δ AICc	Weight
	Fallow	Slope	Aspect	Elevation					
Tree species richness	X				410.34	422.34	423.08	0	0.893
	X			X	405.85	425.85	427.87	4.79	0.081
	X	X			408.36	428.36	430.38	7.3	0.023
	X		X		404.29	432.29	436.29	13.21	0.001
Shrub species richness	X				384.15	396.15	396.89	0	0.940
	X			X	381.73	401.73	403.74	6.85	0.031
	X	X			382.57	402.57	404.59	7.7	0.020
	X		X		374.27	402.27	406.27	9.38	0.009
Herb species richness	X				436.7	448.7	449.44	0	0.906
	X			X	433.7	453.7	455.71	6.27	0.039
	X	X			433.81	453.81	455.82	6.38	0.037
	X		X		428.14	454.14	457.57	8.13	0.016

In Ukhrul, the fallow age was found to have contributed the most to tree, shrub and herb species richness. Besides, slope and elevation also contributed to overall species richness while aspect contributed to tree and shrub species richness as well (Table 7.6). The fallow age was found to have contributed the most to the overall species richness in Chandel which was followed by slope and elevation of the site.

Table 7.6: Summary of LMEM across site's species richness with environmental variables in Manipur

UKHRUL									
Parameter	Explanatory variables				Log Likelihood	AIC	AICc	Δ AICc	Weight
	Fallow	Slope	Aspect	Elevation					
Tree species richness	X				566.19	578.19	578.93	0	0.838
	X		X		551.22	579.22	583.22	4.29	0.098
	X	X			562.68	582.68	584.7	5.77	0.047
	X			X	564.94	584.94	586.96	8.03	0.015
Shrub species richness	X				380.34	392.34	393.08	0	0.470
	X		X		362.21	390.21	394.21	1.13	0.267
	X	X			373.62	393.62	395.64	2.56	0.131
	X	X	X		353.15	389.15	395.92	2.84	0.114
	X			X	378.33	398.33	400.35	7.27	0.012
Herb species richness	X				433.8	445.8	446.55	0	0.889
	X	X			429.19	449.19	451.21	4.66	0.086
	X			X	431.91	451.91	453.92	7.37	0.022
CHANDEL									
Parameter	Explanatory variables				Log Likelihood	AIC	AICc	Δ AICc	Weight
	Fallow	Slope	Aspect	Elevation					
Tree species richness	X				330.43	342.43	344.01	0	0.848
	X	X			324.14	344.14	348.63	4.62	0.084
	X			X	324.66	344.66	349.15	5.14	0.065
Shrub species richness	X				221.7	233.7	234.79	0	0.510
	X	X			212.23	232.23	235.24	0.45	0.407
	X			X	215.94	235.94	238.95	4.16	0.064
	X	X		X	207.39	235.39	241.48	6.69	0.018
Herb species richness	X				446.31	458.31	459.05	0	0.849
	X	X			441.68	461.68	463.9	4.85	0.075
	X			X	442.04	462.04	464.06	5.01	0.069

In Mon, the fallow age was found to have contributed the most to the tree and shrub species richness while fallow age and elevation contributed the most to herb's species richness (Table 7.7). It was observed that slope also contributes to overall species richness. In addition, elevation and aspect contributes to shrub and tree species richness respectively. The fallow age was found to have contributed the most to the overall species richness in Wokha which was followed by slope and elevation of the site.

Table 7.7: Summary of LMEM across site's species richness with environmental variables in Nagaland

MON									
Parameter	Explanatory variables				Log Likelihood	AIC	AICc	Δ AICc	Weight
	Fallow	Slope	Aspect	Elevation					
Tree species richness	X				223.46	235	237	0	0.709
	X	X			214.59	235	239	2.03	0.257
	X			X	219.5	240	244	6.94	0.022
	X		X		209.17	237	247	9.46	0.006
Shrub species richness	X				313.27	325	326	0	0.910
	X			X	309.12	329	332	5.78	0.051
	X	X			309.76	330	333	6.41	0.037
Herb species richness	X			X	384.28	404	406	0	0.534
	X				394.34	406	407	0.78	0.361
	X	X		X	378.8	407	411	4.5	0.056
	X	X			389.22	409	411	4.94	0.045
WOKHA									
Parameter	Explanatory variables				Log Likelihood	AIC	AICc	Δ AICc	Weight
	Fallow	Slope	Aspect	Elevation					
Tree species richness	X				213.44	225	227	0	0.950
	X	X			209.37	229	234	6.83	0.031
	X			X	210.5	231	235	7.96	0.018
Shrub species richness	X				255.86	268	269	0	0.821
	X			X	249.26	269	272	3.32	0.156
	X	X			253.46	273	276	7.52	0.019
Herb species richness	X				373.91	386	387	0	0.945
	X			X	371.11	391	393	6.47	0.037
	X	X			372.76	393	395	8.12	0.016

7.4.6 Species variation in jhum fallow

The percent change in tree, shrub and herb species richness with increasing fallow age in Mizoram is represented in Figure 7.8. It was observed that the tree species richness increases with fallow age while it was contrary in herb's species richness. Shrubs species richness displayed a fluctuating trend with increasing fallow age. Therefore, the tree species recovered by 39.58% from 5 years fallow to 20 years fallow in Mizoram but the herb species declined by 34.09%. Shrubs, on the other hand, did not show any change in the total species richness across the fallow age.

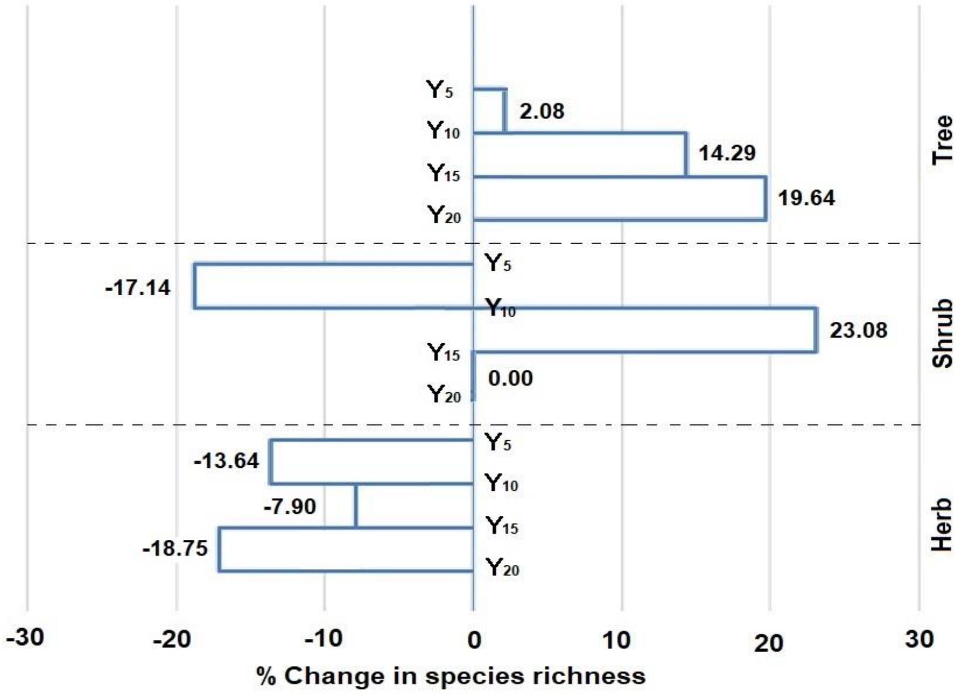


Figure 7.8: percent change in species richness across fallow gradient in Mizoram

In Manipur, it was found that the tree species richness increases with fallow age while it decreases in regard to shrub and herb. It could be concluded that the tree species recovered by 38.24% from 5 years fallow to 20 years fallow and deteriorated by 13.33% and 32% in shrubs and herbs species richness respectively (Figure 7.9).

Corresponding to Manipur, Nagaland too showed an increase in the tree species richness across fallow age while it fluctuates in regard to shrub and herb. It could therefore be concluded that the tree species recovered by 70% from 5 years fallow to 20 years fallow in Nagaland and deteriorated by 8.33% and 18.52% in shrubs and herbs species richness respectively (Figure 7.10).

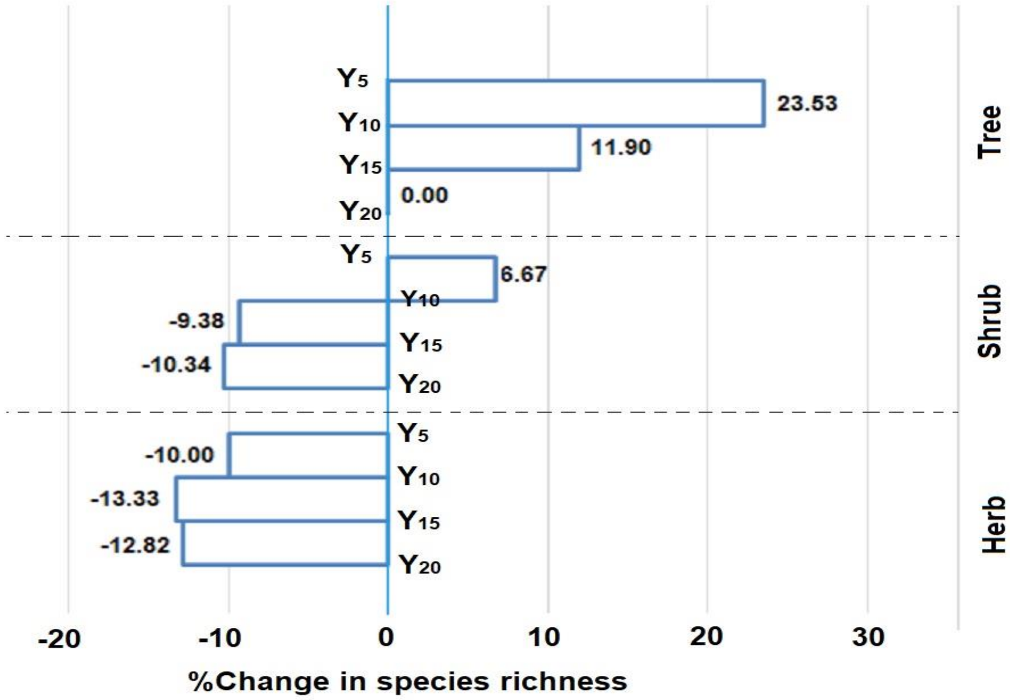


Figure 7.9: percent change in species richness across fallow gradient in Manipur

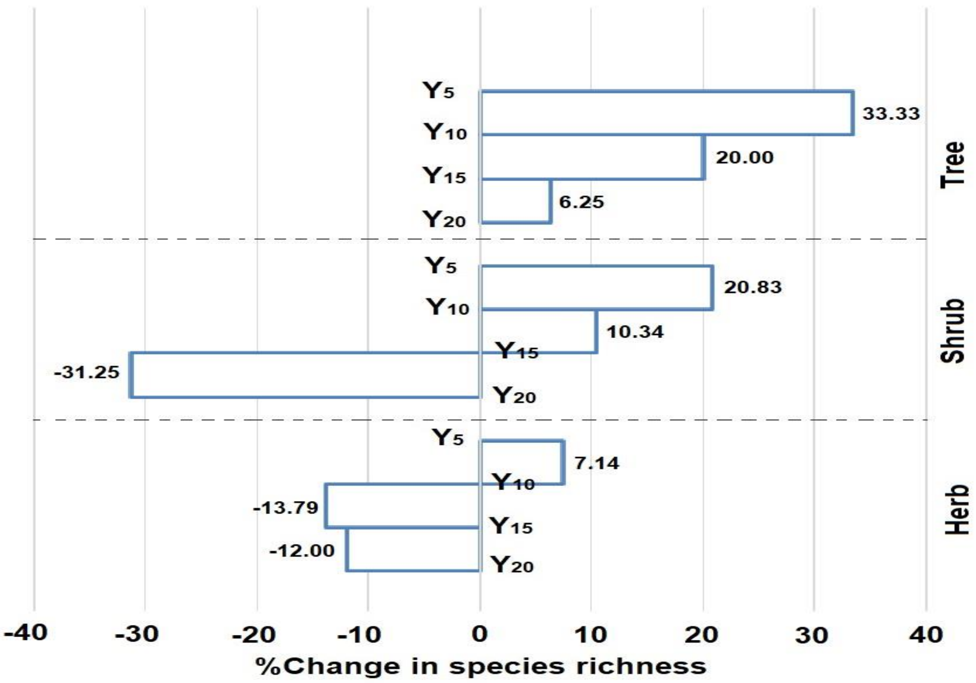


Figure 7.10: percent change in species richness across fallow gradient in Nagaland

7.4.7 Potential tree species for restoration

Some species establishes rapidly after abandonment and continues to grow to mature trees in older fallows. The presence of most of these species appeared to be independent of the environmental factors, suggesting that they are little affected by the slope, aspect, elevation and fallow age of the sites. Three of such species were encountered in Aizawl, Champhai, and one each in Ukhrul, Chandel and Mon. The identified potential species were:

- *Protium serratum* (Wall.ex Colebr.) Engl., *Sapindus mukorossi* Gaertn. and *Magnolia pleiocarpa* (Dandy) Figlar & Noot. in Aizawl (Figure 7.11)
- *Callicarpa arborea* Roxb., *Macaranga indica* Wight and *Macaranga peltata* (Roxb.) Müll. Arg in Champhai (Figure 7.12)
- *Elaeocarpus floribundus* Blume in Ukhrul (Figure 7.13)
- *Castanopsis hystrix* Hook. f. & Thomson ex A. DC. in Chandel (Figure 7.14).
- *Sapindus mukorossi* Gaertn. in Mon (Figure 7.15)

The CCA triplots shows that these species were generalist species, that is, they appear opposite to the direction of increasing value of the environmental variables and its relation with the tree species.

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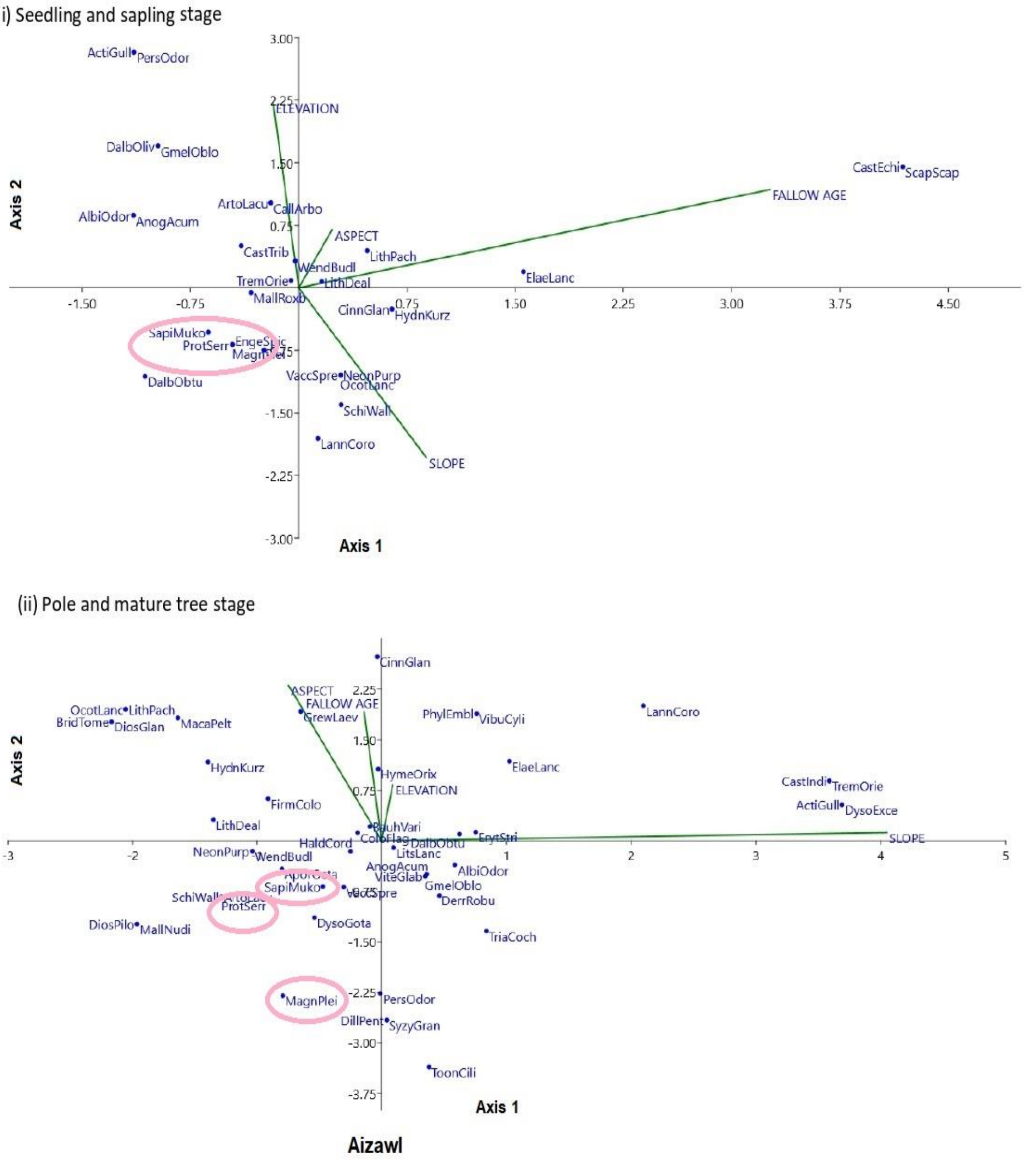
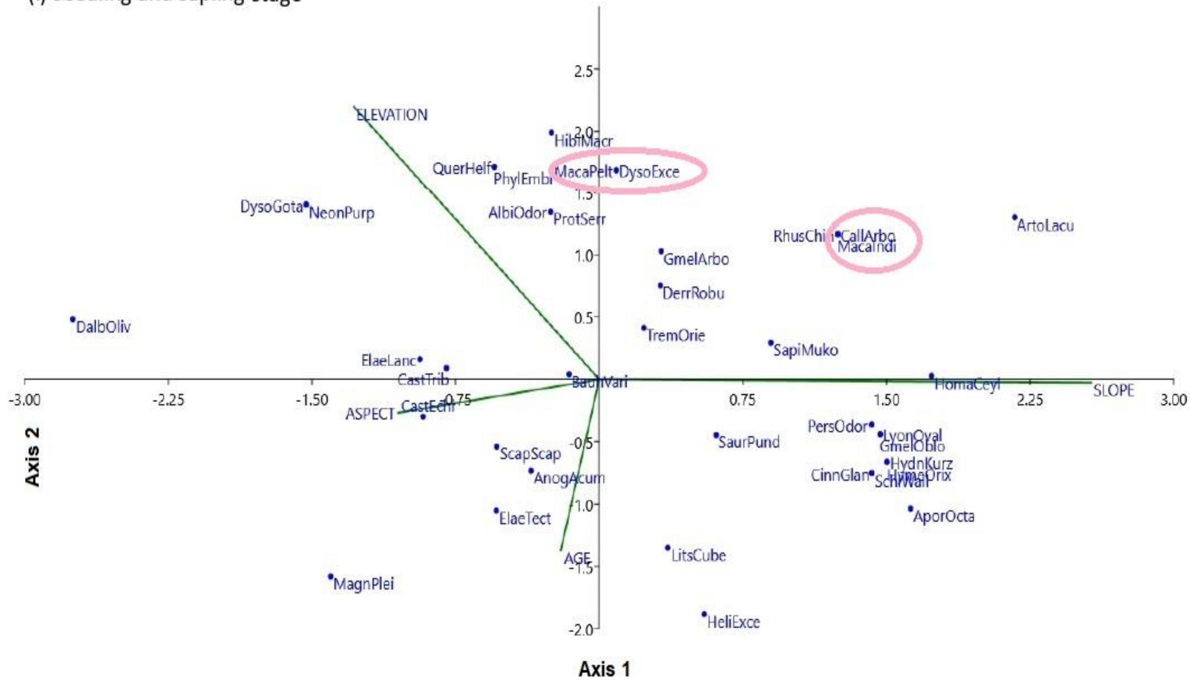


Figure 7.11: CCA triplot of tree species in Aizawl. (i) seedling and sapling stage, and (ii) pole and mature stage in Aizawl from 5 years, 10 years, 15 years and 20 years fallow following shifting cultivation and its relation with selected environmental variables

(i) Seedling and sapling stage



(ii) Pole and mature tree stage

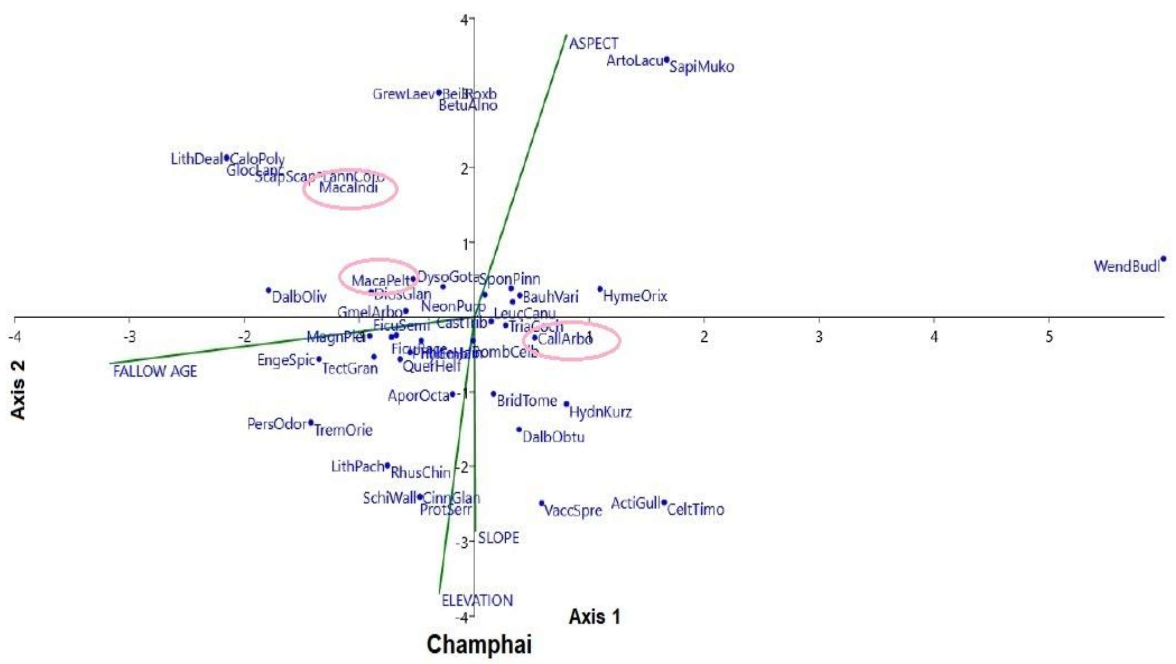


Figure 7.12: CCA triplot of tree species in Champhai. (i) seedling and sapling stage, and (ii) pole and mature stage in Champhai from 5 years, 10 years, 15 years and 20 years fallow following shifting cultivation and its relation with selected environmental variables

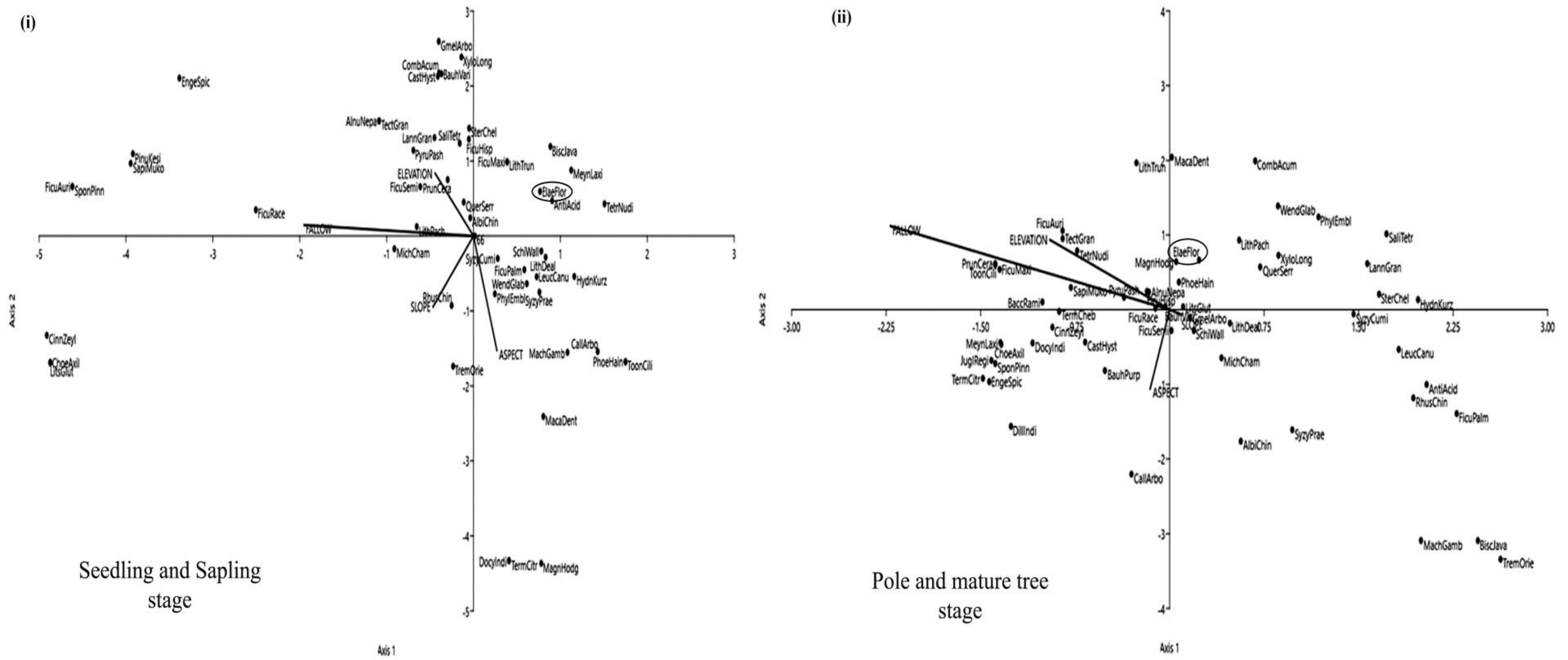


Figure 7.13: CCA triplot of tree species in Ukhrul (i) seedling and sapling stage, and (ii) pole and mature stage in Ukhrul from 5 years, 10 years, 15 years and 20 years fallow following shifting cultivation and its relation with selected environmental variables

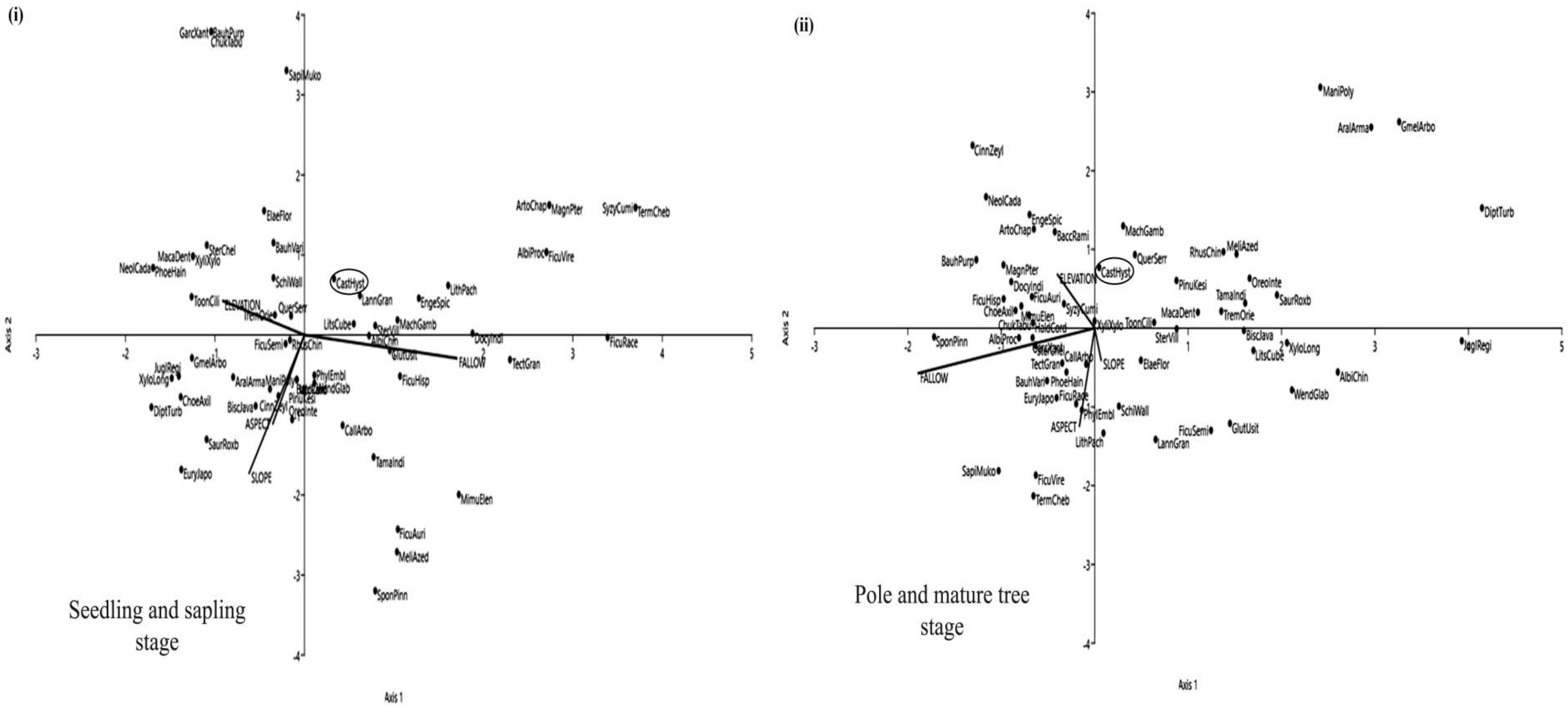


Figure 7.14: CCA triplot of tree species in Chandel (i) seedling and sapling stage, and (ii) pole and mature stage in Chandel from 5 years, 10 years, 15 years and 20 years fallow following shifting cultivation and its relation with selected environmental variables

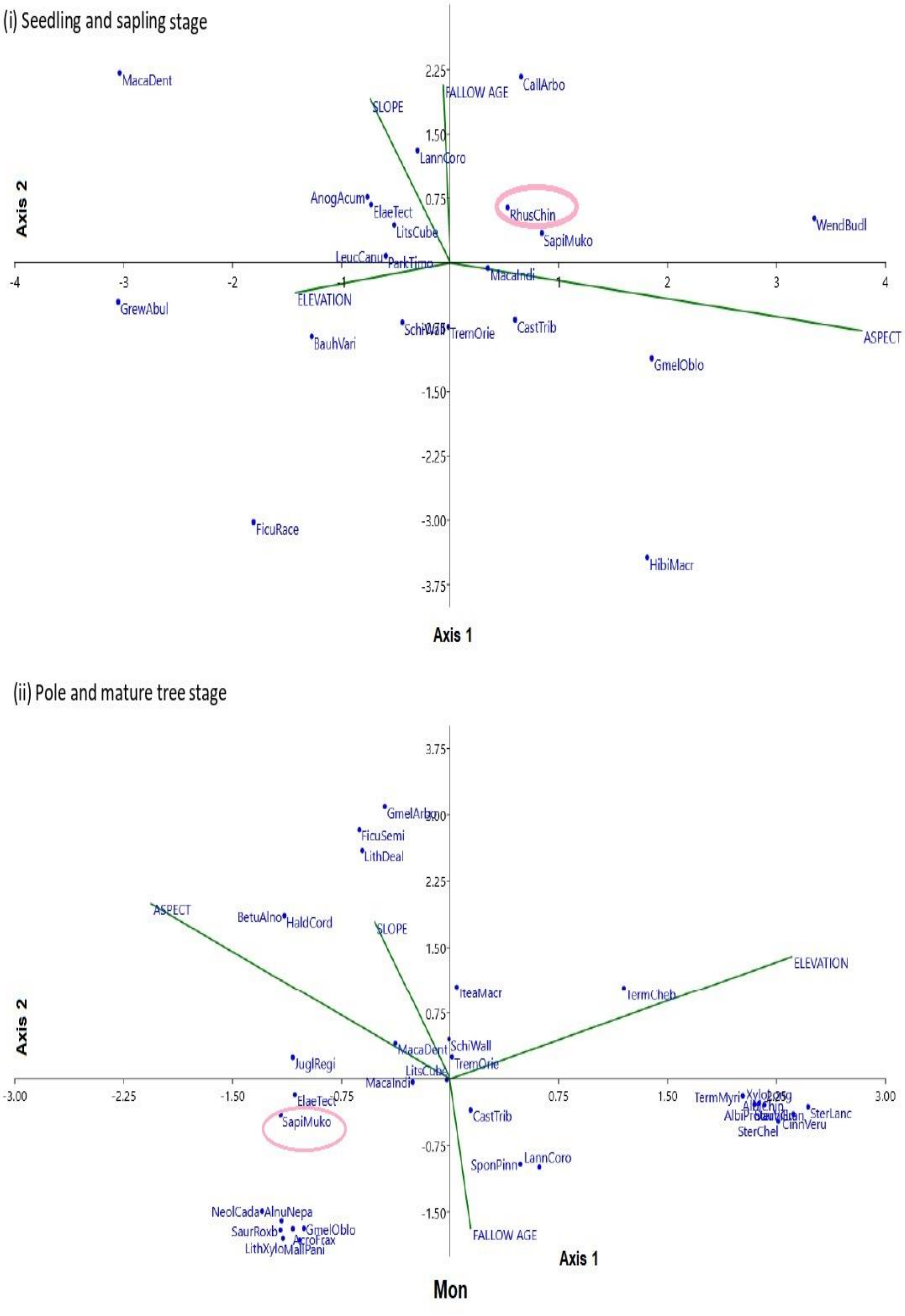


Figure 7.15: CCA triplot of tree species in Mon (i) seedling and sapling stage, and (ii) pole and mature stage in Mon from 5 years, 10 years, 15 years and 20 years fallow following shifting cultivation and its relation with selected environmental variables

7.5 Discussion

The structure of secondary communities after the abandonment of jhum fields generally becomes more complex as a result of species recovery. The findings of this study are in agreement with earlier studies which state that there is an increase in the number of trees with increase in fallow age (Klanderud et al., 2010). The basal area is also considered as an essential predictor of ecological succession, and as reported from similar aged fallows in tropical moist forest, the present study also showed a positive association between basal area and fallow age (Lohbeck et al., 2012). The values of the Shannon-Wiener diversity index (H') and the Margalef species richness index (Dmg) along an increasing fallow gradient indicates high diversity and species richness in the successive communities. The similarity of species between similar aged fallows corresponds with the findings of Toledo and Salick (2006).

The percent recovery of tree species from 5 years fallow to 20 years fallow was more in Champhai because the forest recovery increased with increasing elevation (Lippok et al., 2013). High altitude species have great potential to adapt to diverse micro-climatic situation as high elevation forests are generally open forests and therefore have more ability to recruit in the deforested areas (Homeier et al., 2010). The occurrence and abundance of a total of nine species were found to be independent of any environmental variables, and this suggests that they may be capable of effective restoration of degraded forest areas. The species were *Protium serratum* (Wall.ex Colebr.) Engl., *Sapindus mukorossi* Gaertn. and *Magnolia pleiocarpa* (Dandy) Figlar & Noot. in Aizawl, *Callicarpa arborea* Roxb., *Macaranga indica* Wight and *Macaranga peltata* (Roxb.) Müll. Arg in Champhai, *Elaeocarpus floribundus* Blume in Ukhrul, *Castanopsis hystrix* Hook. f. & Thomson ex A. DC. in Chandel and *Sapindus mukorossi* Gaertn. in Mon. These tree species can be considered as generalist species as they rapidly establish after abandonment and survive in dense forest. Since both the species occur naturally in wild, they can be utilized for active restoration to accelerate the recovery process of fallows.

Chapter 8

Soil Nutrient Status at different stages of succession after abandonment of jhum

8.1 Introduction

An understanding of factors controlling nutrient cycling can help in effective management of nutrient cycling of forests and soil nutrient restoration in degraded ecosystems. One of the ecologically sensitive human-made ecosystems is shifting cultivation (locally called jhum cultivation), which is the most prevalent form of food production practice in the hills of the humid tropics, particularly in the highly rugged, fragile, and inaccessible mountain slopes. This system is often abandoned in the event of lowered crop production, because these low-to-no input agricultural systems cannot sustain continued cultivation beyond two or three years of cropping period (Ramakrishnan, 1992). The stability of jhum depends upon the recovery and maintenance of soil fertility. If the nutrients lost or displaced during cropping period are balanced the fallow phase, the system could continue sustainably.

Shifting cultivation is widely practiced in several tropical countries, about 30% of the mountain region of the world (FAO 2010), where it still represents one of the dominant agricultural practices (Baccini et al., 2012). Jhum has an integrated mechanism of livelihood and conservation as it contributes both to preserve the agro-biodiversity, in particular the germplasm of native crops, and to control weeds and pathogens of the soil (Tripathi and Barik, 2003). However, this practice became unsustainable mainly because of the population increase, and consequent increase in the demand for food. The consequence of this is a reduction of the cultivation cycle time, which results in a negative impact on the soil system due to the increase of erosion and loss of organic matter and nutrients. Furthermore, at the end of the cultivation forest degradation occurs due to formation of secondary forests at the expense of primary ones (Patel et al., 2013). Length of the fallow is important for soil fertility restoration and improvement of soil properties. The difference in soil properties results in local variations in vegetation structure and composition. The assessment of the impacts on soil caused by shifting cultivation, with a focus on maintaining and improving soil quality is crucial point for the development of a strategy to promote agricultural productivity and the environment quality in the northeast of the Himalayas (Das et al., 2016). It was suggested by Shimrah et al. (2015) that a minimum fallow period of seven years was necessary to provide adequate soil nutrients and vegetation in the humid subtropical upland landscape of North-East India. Significant change in the soil organic carbon from conversion of natural forest to cropland have affect soil fertility in the Tropics (Brown and Lugo, 1990; Ramakrishnan et al., 2003). Secondary forest succession can be an effective and low-cost strategy to increase forest cover and the associated biodiversity and soil functions. However, little is known about how soil functions develop during succession, and how vegetation attributes influence soil functions, especially in highly biodiverse and fragmented landscapes in the tropics. And therefore, this chapter is an attempt to assess the soil nutrient status across an increasing fallow gradient and its relation with species composition of the fallow stands.

8.2 Materials and methods

8.2.1 Site selection

Keeping in view the topographical parameters, soil type, and mean annual rainfall and temperature, four different fallow periods after the abandonment of the jhum fields were selected, namely, 5 (JF_5), 10 (JF_{10}), 15 (JF_{15}) and 20 (JF_{20}) years fallow (see Table 7.1). The study sites were selected as per the findings of Chapter 4 and the plot was navigated using a GPS.

8.2.2 Soil sampling

Within each quadrat selected for vegetation analysis, soil sample were collected at two depths: 0-15 cm and 15-30 cm each. Samples from same age fallow were thoroughly mixed to get a composite sample, and then 3 replicates were drawn. The soil samples were air dried, crushed and grounded to pass through a 2 mm sieve and then analyzed for different chemical properties of the soil. The pH was determined in 1:2 soil water suspensions using digital pH meter. In addition, Available Nitrogen, Available Phosphorus, Available Potassium and Soil Organic Carbon were determined following the standard analysis protocol (Subbiah and Asija, 1956; Bray and Kurtz, 1945; Hanway and Heidel, 1952; Walkley and Black, 1934 respectively).

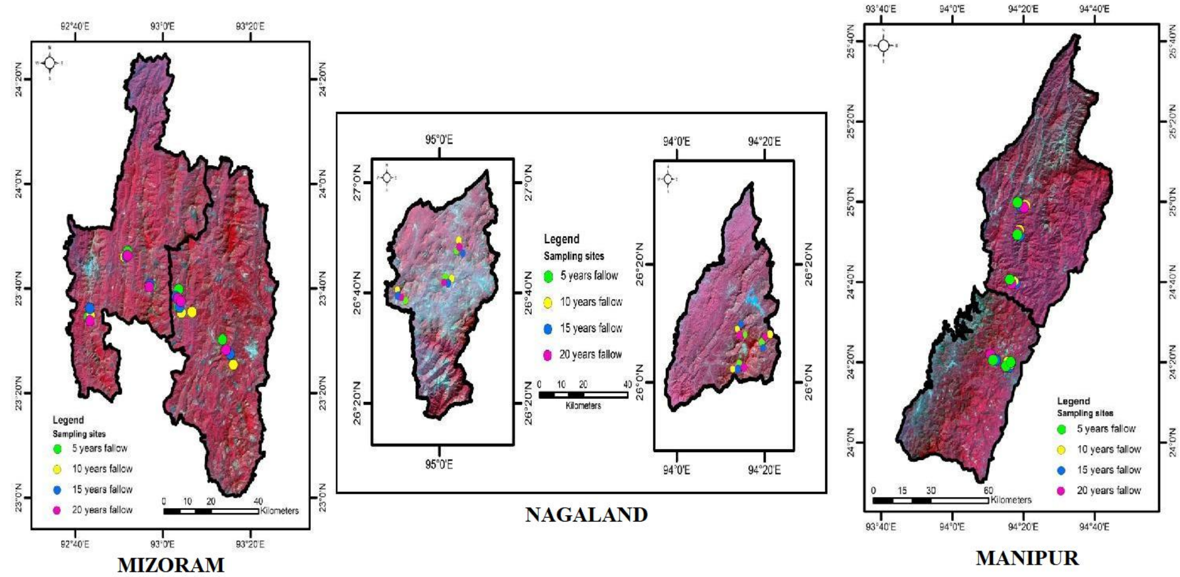


Figure 8.1: Map showing the location of the study sites (soil sampling)

8.3 Statistical analysis

The individual variables such as soil pH, Available N, Available P, Available K and Soil Organic Carbon (SOC) were analyzed using a two way analysis of variance (ANOVA). The first factor was fallow age with four levels (5, 10, 15 and 20 years fallow) and second factor was soil depth with 2 levels (0-15 and 15-30 cm). Pearson's correlation test was used to understand the nature of relationship between the soil parameters and species abundance in each fallow stand, while linear regression was applied to determine the extent of contribution made by the soil parameters in explaining the variation in species abundance across an increasing fallow gradient.

8.4 Result and discussion

8.4.1 Soil properties across fallow ages

The chemical properties of the studied sites are shown in Tables 8.1, 8.2 8.3, 8.4, 8.5 and 8.6. It was found that the pH decreased with depth in each soil profile as per the findings of Hanawalt & Whittaker (1976). As the fallow aged, acidity decreased and showed recovery of soil and buffering capacity. The differences in the soil pH among the different fallow can be due to the variations in uptake of exchangeable base cations by the growing vegetation or vegetation cover, nitrogen fixation and litter production and accumulation (Githae et al., 2011). The organic C content was between 0.52% and 3.59% and decreases with depth which corresponds with the finding of Moges et al. (2013). The organic C content however increase with fallow age which is at par with the results of Deng et al. (2013), Ferreira et al. (2018) and Hall et al. (2017).

Table 8.1: Chemical properties of soil at different depth in Champhai district of Mizoram (±SE)

CHAMPHAI	Fallow age	Soil depth	pH	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	Organic carbon (%)
Dulte	5 years	0-15	4.91±0.02	74±2.06	2.08±0.05	64±0.64	1.98±0.04
		15-30	4.61±0.03	67.33±2.17	1.58±0.07	38.87±0.59	1.34±0.02
	10 years	0-15	5.14±0	127.33±1.33	2.29±0.06	96.63±1.08	1.72±0.01
		15-30	4.86±0.01	114±1.92	1.42±0.06	68.87±0.68	1.27±0.04
	15 years	0-15	4.83±0.13	157.33±2.67	2.06±0.07	76±1.94	2.38±0.01
		15-30	4.92±0.02	132±3.31	1.63±0.03	41.13±0.44	2.1±0.03
	20 years	0-15	5.21±0.01	166.67±4.16	4.8±0.25	55.07±2.54	2.51±0.05
		15-30	5.13±0.02	132±3.76	1.84±0.09	37.5±1.80	2.40±0.04
Chhungte	5 years	0-15	4.75±0.05	90±1.15	1.93±0.04	65.53±1.58	0.92±0.02
		15-30	4.57±0.03	75.33±1.33	1.41±0.02	35.43±0.62	0.73±0.04
	10 years	0-15	5.1±0	100.67±2.67	1.9±0.05	57.27±1.81	1.61±0.01
		15-30	4.84±0.04	84.67±2.40	1.61±0.05	33.33±0.69	1.04±0.01
	15 years	0-15	5.19±0.03	114±1.92	2.09±0.04	53.87±0.94	1.83±0.03
		15-30	5.03±0.01	100.67±1.76	1.26±0.06	29.97±0.81	1±0.02
	20 years	0-15	5.28±0.02	143.33±2.67	3.29±0.05	46.8±1.11	2.66±0.03
		15-30	5.15±0.01	116±2.15	1.84±0.06	29.83±1.17	2.47±0.01
Kawlkulh	5 years	0-15	5.09±0.03	79.67±1.76	3.8±0.27	82±1.15	2.24±0.02
		15-30	4.79±0.01	60±1.93	1.66±0.03	59.33±1.33	2.06±0.01
	10 years	0-15	5.15±0.02	107.33±1.33	2.11±0.05	54.93±0.58	2.44±0.06
		15-30	5.02±0.01	89.33±1.76	1.23±0.06	29.67±1.42	2.33±0.02
	15 years	0-15	5.14±0.01	116.67±2.40	2.01±0.03	66.67±2.24	1.64±0.04
		15-30	4.92±0.02	98.67±0.67	1.55±0.02	35.67±0.83	1.27±0.02
	20 years	0-15	5.24±0	147.33±1.76	2.08±0.01	49.83±0.27	1.47±0.02
		15-30	5.06±0.03	103±2.51	1.38±0.01	32±1.72	1.15±0.01

Table 8.2: Chemical properties of soil at different depth in Aizawl district of Mizoram (±SE)

AIZAWL	Fallow age	Soil depth	pH	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	Organic carbon (%)
Sesawng	5 years	0-15	4.96±0.02	93.18±1.25	1.82±0.02	115.33±1.40	1.29±0.03
		15-30	4.83±0.01	78.99±1.06	1.62±0.02	77.74±0.70	0.90±0.01
	10 years	0-15	5.19±0.01	136.67±0.67	2.9±0.03	71.91±0.97	1.47±0.02
		15-30	4.98±0.03	109.5±1.40	2.47±0.01	56.18±0.50	1.05±0.01
	15 years	0-15	5.29±0	167.2±2.41	4.3±0	58.24±0.78	2±0.03
		15-30	5.03±0.02	121±1.00	3.59±0.02	45.64±0.41	1.40±0.01
	20 years	0-15	5.47±0.03	183.67±1.73	4.93±0.01	42.13±0.38	2.15±0.01
		15-30	5.64±0.02	127.61±1.71	3.85±0.05	32.61±0.29	1.50±0.03
Muallungthu	5 years	0-15	5.03±0.01	79.33±1.86	1.66±0.02	96.17±0.19	1.54±0.01
		15-30	4.81±0.02	78.99±1.06	1.58±0.04	62±1.53	0.96±0.02

	10 years	0-15	5.31±0	113.33±2.53	1.77±0.09	73.33±0.18	1.89±0.03
		15-30	5.13±0.03	109.67±1.20	1.72±0.02	48.83±0.60	1.25±0.01
	15 years	0-15	5.11±0.06	154.67±2.53	2.9±0.07	58±0	3.28±0.26
		15-30	4.9±0	117.33±1.76	2.35±0.01	41.52±0.56	1.73±0.03
	20 years	0-15	5.53±0.03	157.97±2.12	3.20±0.04	53.17±0.71	3.16±0.01
		15-30	5.22±0.02	126±1.93	2.72±0.03	38.47±0.17	2.17±0.05
Keifang	5 years	0-15	5.37±0.01	104.93±2.89	2.23±0.02	113.43±1.52	1.27±0.02
		15-30	5.13±0.01	87.4±1.30	1.61±0.01	77.67±1.01	1.05±0.04
	10 years	0-15	5.65±0.02	128.6±0.95	3.09±0.04	58.24±0.78	1.54±0.01
		15-30	5.44±0.01	92.73±1.27	2.46±0.02	45.64±0.41	1.16±0.03
	15 years	0-15	5.64±0.02	160.02±2.15	3.50±0.05	71.33±0.88	1.94±0.25
		15-30	5.33±0.04	109.38±1.47	2.23±0.03	53.33±1.76	1.80±0.13
	20 years	0-15	5.76±0.08	154.67±2.67	3.85±0.05	42.54±0.57	2.47±0.08
		15-30	5.47±0.02	127.61±1.71	2.52±0.03	32.60±0.29	2.29±0.03

Table 8.3: Chemical properties of soil at different depth in Ukhrul district of Manipur (±SE)

UKHRUL	Fallow age	Soil depth	pH	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	Organic carbon (%)
Shakok	5 years	0-15	4.96±0.09	102.67±4.67	3.29±0.07	258.33±4.29	2.23±0.05
		15-30	4.81±0.08	186.67±4.27	2.46±0.06	244.83±2.89	1.94±0.04
	10 years	0-15	4.99±0.09	139.07±2.49	10.68±0.19	233.17±3.46	3.1±0.06
		15-30	4.83±0.06	135.33±3.49	5.36±0.05	190.5±4.65	3.55±0.06
	15 years	0-15	5.07±0.08	140±0	15.33±0.24	197±3.21	2.64±0.05
		15-30	5.02±0.11	130.67±4.62	12.83±0.28	181.5±3.47	2.72±0.06
	20 years	0-15	5.79±0.09	158.67±4.57	12.69±0.13	180.33±3.47	2.84±0.04
		15-30	5.46±0.10	135.33±4.52	10.74±0.08	167.17±1.59	2.65±0.02
Shangshak	5 years	0-15	4.95±0.12	74.67±4.49	3.29±0.09	128±5.12	0.79±0.05
		15-30	4.92±0.06	79.33±4.16	2.43±0.09	78.33±1.18	0.54±0.01
	10 years	0-15	5.08±0.19	135.33±4.46	11.44±0.28	377.83±9.16	1.06±0.03
		15-30	4.82±0.16	126±6.04	2.88±0.04	110±2.65	1.76±0.01
	15 years	0-15	4.72±0.29	172.67±4.67	2.89±0.03	223.33±3.53	1.45±0.02
		15-30	5.01±0.05	140±0	2.61±0.01	154±3.21	2.49±0.05
	20 years	0-15	5.06±0.28	163.33±4.29	3.02±0.07	104.67±4.06	1.9±0.03
		15-30	4.77±0.23	140±0	2.55±0.06	90.5±1.04	2.82±0.02
Kasom Khullen	5 years	0-15	4.53±0.04	93.33±4.37	2.71±0.05	161.83±4.67	3.07±0.07
		15-30	4.66±0.07	98±0	2.75±0.08	153.33±4.19	2.43±0.06
	10 years	0-15	4.55±0.05	154±0	3±0.07	118.67±2.91	2.34±0.05
		15-30	4.57±0.13	116.67±3.94	2.34±0.06	94.5±2.89	1.04±0.03
	15 years	0-15	5.22±0.08	196±6.49	3±0.07	180.83±5.26	3.41±0.11
		15-30	5.34±0.07	196±7.14	2.6±0.05	102.33±4.21	2.44±0.06
	20 years	0-15	5.29±0.13	219.33±4.37	3.16±0.03	188.83±4.67	3.49±0.05
		15-30	5.43±0.11	214.67±3.94	3.04±0.03	170.33±3.61	2.68±0.08

Table 8.4: Chemical properties of soil at different depth in Chandel district of Manipur (±SE)

CHANDEL	Fallow age	Soil depth	pH	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	Organic carbon (%)
Kongkhang	5 years	0-15	5.3±0.02	256.67±2.67	2.92±0.08	55.5±1.44	2.5±0.08
		15-30	5.36±0.01	196±0	3±0.05	205±2.29	2.23±0.04
	10 years	0-15	5.2±0.03	154±0	3.01±0.05	83.17±1.64	3.34±0.06
		15-30	5.23±0.11	116.67±2.15	2.62±0.06	46.91±1.17	1.71±0.03
	15 years	0-15	4.95±0.03	266±4.62	2.74±0.05	44.5±1.61	1.59±0.03
		15-30	5.04±0.05	270.67±2.73	2.74±0.03	77.33±1.30	1.05±0.02
	20 years	0-15	4.73±0.04	280±0	2.68±0.05	135.5±3.77	3.43±0.01
		15-30	4.79±0.07	261.33±2.51	2.87±0.04	88.83±1.07	1.66±0.03
Kwatha	5 years	0-15	5.06±0.05	140±0	2.74±0.05	148.83±3.76	2.83±0.05
		15-30	4.89±0.11	186.67±2.19	2.89±0.04	73.67±1.29	1.44±0.03
	10 years	0-15	5.27±0.02	214.67±2.67	2.86±0.05	127±2.62	2.75±0.05
		15-30	5.2±0.02	200.67±2.73	3.19±0.08	64.5±1.80	1.49±0.02
	15 years	0-15	5.29±0.08	219.33±2.15	3.66±0.07	99.83±2.33	2.77±0.04
		15-30	5.34±0.014	228.67±2.14	2.66±0.10	113±3.01	1.69±0.06
	20 years	0-15	5.43±0.012	247.33±2.15	3.44±0.06	133.67±1.59	2.78±0.03
		15-30	5.34±0.03	224±0	2.87±0.05	114.67±1.76	1.6±0.01
Khudengthabi	5 years	0-15	5.24±0.09	158.67±2.43	2.89±0.06	65.01±7.29	2.86±0.04
		15-30	5.07±0.07	182±0	2.61±0.05	65.17±1.30	1.66±0.02
	10 years	0-15	5.21±0.08	191.33±2.16	3.15±0.04	55.67±1.01	3.19±0.05
		15-30	5.09±0.05	228.67±2.63	2.76±0.05	48.33±0.88	2.18±0.03
	15 years	0-15	5.28±0.11	210±0	2.63±0.07	69.5±1.26	1.95±0.02
		15-30	5.41±0.05	112±0	2.49±0.04	36.33±0.59	1.17±0.02
	20 years	0-15	5.3±0.02	242.67±2.34	2.68±0.05	61±3.04	2.17±0.05
		15-30	5.41±0.03	200.67±2.49	2.31±0.02	47.83±0.88	1.41±0.06

Table 8.5: Chemical properties of soil at different depth in Mon district of Nagaland (±SE)

MON	Fallow age	Soil dept	pH	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	Organic carbon (%)
Wakching	5 years	0-15	4.83±0.03	125±1.73	5.86±0.17	66±1.91	2.5±0.07
		15-30	4.67±0.02	109.27±2.57	4.03±0.09	26±0.45	1.4±0.02
	10 years	0-15	4.9±0	146±2.21	6.90±0.20	64±1.85	2.54±0.07
		15-30	4.9±0.06	89.51±1.55	3.83±0.07	35.76±0.84	1.38±0.03
	15 years	0-15	5.17±0.03	162.54±2.35	7.53±0.11	52.65±0.93	2.66±0.05
		15-30	5±0.06	86.49±2.51	3.90±0.17	35±1.01	1.48±0.04
	20 years	0-15	5.3±0	162.91±3.83	7.75±0.18	45.15±0.65	2.74±0.04
		15-30	5±0.03	100.93±1.94	4.18±0.07	29.8±0.53	1.61±0.02
Yuting	5 years	0-15	4.6±0.06	120±2.46	6.08±0.16	70±1.02	2.41±0.07
		15-30	4.5±0.12	65.22±0.94	3.09±0.07	39.73±0.93	1.32±0.03
	10 years	0-15	4.8±0.12	137.58±2.44	6.56±0.10	64.21±0.76	2.6±0.06
		15-30	4.8±0.05	80±2.31	4.09±0.12	38±1.10	1.32±0.04
	15 years	0-15	4.67±0.09	147.01±3.45	8.42±0.14	54±0.94	2.7±0.04
		15-30	4.3±0.12	75.49±1.34	4.34±0.10	0.7432±	1.32±0.03
	20 years	0-15	4.97±0.09	172.57±2.50	8.99±0.13	63.21±0.95	2.96±0.07
		15-30	4.87±0.08	94±2.71	5.52±0.16	38.5±1.11	1.72±0.05
Phuktong	5 years	0-15	4.77±0.06	144±2.16	7.4±0.21	60±1.72	2.7±0.08

		15-30	4.57±0.09	68.23±0.99	3.31±0.05	38±0.66	1.6±0.03
	10 years	0-15	5.1±0.12	162±2.81	8.26±0.14	77.48±1.82	2.77±0.04
		15-30	5±0.08	85.43±2.01	4.43±0.08	46±0.80	1.54±0.07
	15 years	0-15	5.03±0.18	174±3.02	8.68±0.25	62±1.79	2.75±0.08
		15-30	4.6±0.06	82.27±1.19	4.88±0.11	32.11±0.26	1.59±0.02
	20 years	0-15	5.4±0.17	184.76±2.34	8.84±0.15	63±1.05	3±0.07
		15-30	4.93±0.09	81.45±1.45	5.08±0.07	38.63±0.56	1.7±0.04

Table 8.6: Chemical properties of soil at different depth in Wokha district of Nagaland (±SE)

WOKHA	Fallow age	Soil depth	pH	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	Organic carbon (%)
Longsa	5 years	0-15	4.7±0.06	155±2.47	8.18±0.24	96±2.77	2.48±0.07
		15-30	4.5±0.04	98±2.83	6.34±0.18	58.61±1.04	1.58±0.05
	10 years	0-15	4.8±0.12	180±3.12	9.5±0.27	102±2.94	3.30±0.08
		15-30	4.83±0.03	131.12±2.33	6.32±0.09	77.76±1.13	1.85±0.03
	15 years	0-15	4.8±0.11	218±2.29	11.09±0.32	83.44±1.96	3.49±0.01
		15-30	4.57±0.09	146±2.53	7.99±0.14	46.15±0.67	1.92±0.04
	20 years	0-15	4.6±0.21	191±3.51	11.51±0.20	76±2.19	3.39±0.10
		15-30	4.7±0.12	119.2±2.80	8.16±0.19	26±0.75	1.85±0.07
Riphim	5 years	0-15	4.8±0.17	178±3.08	9.2±0.21	124±2.58	2.30±0.05
		15-30	4.6±0.09	120.4±1.74	8.04±0.19	80.5±1.39	1.69±0.03
	10 years	0-15	4.9±0.07	184.61±2.67	11.52±0.17	108.5±1.88	2.61±0.05
		15-30	4.8±0.06	114±3.29	8.69±0.25	70.5±1.22	1.7±0.05
	15 years	0-15	5±0.12	202.64±2.76	11.5±0.20	71.52±1.68	2.94±0.06
		15-30	4.8±0.09	132.44±1.92	7.66±0.18	34±0.59	2.08±0.04
	20 years	0-15	05.2±0.12	240±3.93	13.42±0.28	74±1.28	3.28±0.08
		15-30	5.03±0.09	162.91±2.89	8.70±0.15	39.5±1.14	1.9±0.03
Selukhu	5 years	0-15	4.5±0.10	128±3.70	7.2±0.21	158±365	2.45±0.07
		15-30	4.5±0.12	98±2.83	5.8±0.17	75±1.73	1.7±0.05
	10 years	0-15	4.7±0.06	154.51±2.24	9.44±0.22	149.49±2.51	3.38±0.08
		15-30	4.77±0.09	119.2±2.80	6.24±0.14	85.92±0.02	1.93±0.05
	15 years	0-15	4.7±0.06	196±3.39	11.45±0.20	146±2.21	3.45±0.07
		15-30	4.5±0.12	166.88±3.92	6.86±0.16	64±1.85	1.78±0.04
	20 years	0-15	4.93±0.15	216±6.24	11.82±0.24	132±3.81	3.23±0.07
		15-30	4.7±0.12	164±2.73	7.6±0.22	79.5±2.29	1.36±0.04

8.4.2 Soil nutrient status at different depths across fallow ages

Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Champhai and Aizawl is represented in Table 8.7 and 8.8 respectively.

In Champhai, Older fallow age was found to have higher values of pH, available N and P. Significant difference in nutrient value was found between 5 years and 20 years fallow ($P<0.05$), and little or insignificant change between successive 5 years interval. On the other hand, organic C content in soil of the studied sites increased slowly with time having no significant difference till 20 years. In Aizawl, the nutrient status of jhum fallows was found to have significant change with time. Increase in pH, N, P and C was observed in both soil depths following increase in fallow age. Tukey HSD post hoc test also showed significant difference in the nutrient value of fallow sites with 5 years age difference.

Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Ukhrul and Chandel is represented in Table 8.9 and 8.10 respectively.

In Ukhrul, increase in soil nutrient properties was seen in pH, N, P, C and vice versa in K. However, only pH and available N showed significant difference between fallow years with the post hoc test. Champhai showed less difference of soil nutrient status of jhum fallows with increasing fallow age.

Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Mon and Wokha is represented in Table 8.11 and 8.12 respectively. In Mon, older fallow areas were found to have higher concentration of soil nutrients. ANOVA analysis also showed significant change in nutrient values between different fallow ages. In Wokha, Significant change in concentration of N, P and C was observed in 0-15 soil depth, while all parameters (pH, N, P, K and C) was found to differ significantly in 15-30 cm depth. The pH, N, P and C showed increasing trend in concentration with fallow age while vice versa for K.

Table 8.7: Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Champhai

Parameter	0-15 depth				15-30 depth			
	5 years	10 years	15 years	20 years	5 years	10 years	15 years	20 years
pH	4.9±0.06^{a}	5.13±0.01^{ab}	5.05±0.11^{ab}	5.24±0.01^{bc}	4.65±0.04^{A}	4.91±0.03^{B}	4.96±0.02^{B}	5.11±0.01^{C}
Available N	81.22±2.58^{a}	111.78±4.12^{b}	129.33±7.20^{b}	152.44±4.37^{c}	67.56±2.70^{A}	96.00±4.67^{B}	110.44±5.55b^{C}	117.00±4.50^{C}
Available P	2.61±0.32^{ab}	2.10±0.06^{a}	2.06±0.03^{a}	3.39±0.61^{b}	1.55±0.04^{ABC}	1.42±0.06^{B}	1.48±0.06^{AB}	1.68±0.08^{AC}
Available K	70.51±2.94^{a}	69.61±6.81^{a}	65.51±3.34^{ab}	50.57±1.45^{bc}	44.54±3.76^{A}	43.96±6.27^{A}	35.59±1.65^{A}	33.11±1.39^{A}
Organic C	1.71±0.20^{a}	1.92±0.13^{a}	1.95±0.11^{a}	2.22±0.19^{a}	1.38±0.19^{A}	1.54±0.20^{A}	1.46±0.17^{A}	2.01±0.22^{A}

Value with same letter have no significant difference (P>0.05, Tukey's HSD test)

Table 8.8: Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Aizawl

Parameter	0-15 depth (cm)				15-30 depth (cm)			
	5 years	10 years	15 years	20 years	5 years	10 years	15 years	20 years
pH	5.12±0.06^{a}	5.38±0.07^{b}	5.35±0.08^{ab}	5.58±0.05^{b}	4.92±0.05^{A}	5.18±0.07^{B}	5.09±0.06^{AB}	5.45±0.06^{C}
Available N	92.48±3.85^{a}	126.20±3.58^{b}	160.63±2.29^{c}	165.44±4.88^{c}	81.80±1.51^{A}	103.97±3.02^{B}	115.91±1.86^{C}	127.08±0.95^{D}
Available P	1.90±0.09a	2.59±0.21^{ab}	3.57±0.20^{c}	3.99±0.25^{c}	1.60±0.01^{A}	2.21±0.12^{AB}	2.72±0.22^{BC}	3.03±0.21^{C}
Available K	108.31±3.16^{a}	67.83±2.43^{b}	62.52±2.23^{b}	45.95±1.83^{c}	72.47±2.68^{A}	50.22±1.58^{B}	46.83±1.81^{B}	34.56±0.99^{C}
Organic C	1.37±0.04^{a}	1.63±0.07^{a}	2.41±0.24^{b}	2.59±0.15^{b}	0.97±0.02^{A}	1.15±0.03^{A}	1.65±0.07^{B}	1.99±0.12^{C}

Value with same letter have no significant difference (P>0.05, Tukey's HSD test)

Table 8.9: Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Ukhrul

Parameter	0-15 depth				15-30 depth			
	5 years	10 years	15 years	20 years	5 years	10 years	15 years	20 years
pH	4.81 ± 0.09^{a}	4.87 ± 0.10^{a}	5.00 ± 0.13^{ab}	5.38 ± 0.14^{b}	4.80 ± 0.05^{AB}	4.74 ± 0.08^{B}	5.12 ± 0.07^{AC}	5.22 ± 0.14^{C}
Available N	90.22 ± 4.73^{a}	142.80 ± 3.23^{b}	$169.56\pm8.56b^{c}$	180.44 ± 10.02^{c}	121.33 ± 16.66^{A}	126.00 ± 4.04^{A}	155.56 ± 10.55^{A}	163.33 ± 12.99^{A}
Available P	3.10 ± 0.10^{a}	8.37 ± 1.35^{a}	7.07 ± 2.07^{a}	6.29 ± 1.60^{a}	2.55 ± 0.06^{A}	3.53 ± 0.47^{A}	6.01 ± 1.71^{A}	5.44 ± 1.33^{A}
Available K	182.72 ± 19.69^{a}	243.22 ± 37.66^{a}	200.39 ± 6.53^{a}	157.94 ± 13.53^{a}	158.83 ± 24.12^{A}	131.67 ± 14.98^{A}	145.94 ± 11.75^{A}	142.67 ± 13.10^{A}
Organic C	2.03 ± 0.33^{a}	2.17 ± 0.30^{a}	2.50 ± 0.29^{a}	2.74 ± 0.23^{a}	1.64 ± 0.28^{A}	1.72 ± 0.19^{A}	2.55 ± 0.05^{B}	2.72 ± 0.04^{B}

Value with same letter have no significant difference ($P>0.05$, Tukey's HSD test)

Table 8.10: Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Chandel

Parameter	0-15 depth				15-30 depth			
	5 years	10 years	15 years	20 years	5 years	10 years	15 years	20 years
pH	5.20 ± 0.05^{a}	5.23 ± 0.03^{a}	5.17 ± 0.07^{a}	5.15 ± 0.12^{a}	5.11 ± 0.09^{A}	5.17 ± 0.04^{A}	5.26 ± 0.07^{A}	5.18 ± 0.10^{A}
Available N	185.11 ± 18.19^{a}	186.67 ± 9.04^{a}	231.78 ± 9.07^{b}	256.67 ± 6.17^{b}	188.22 ± 2.46^{A}	182.00 ± 16.99^{A}	203.78 ± 23.81^{A}	228.67 ± 9.04^{A}
Available P	2.85 ± 0.04^{a}	3.01 ± 0.05^{a}	3.01 ± 0.17^{a}	2.93 ± 0.13^{a}	2.83 ± 0.07^{A}	2.86 ± 0.09^{A}	2.63 ± 0.05^{A}	2.68 ± 0.10^{A}
Available K	89.78 ± 17.51^{a}	88.61 ± 10.49^{a}	71.28 ± 8.05^{a}	110.06 ± 16.07^{a}	114.61 ± 22.65^{A}	53.25 ± 2.90^{B}	75.56 ± 11.18^{AB}	83.78 ± 9.75^{AB}
Organic C	2.73 ± 0.07^{a}	3.09 ± 0.09^{a}	2.10 ± 0.18^{b}	2.79 ± 0.18^{a}	1.78 ± 0.12^{A}	1.79 ± 0.10^{A}	1.30 ± 0.10^{B}	1.56 ± 0.04^{AB}

Value with same letter have no significant difference ($P>0.05$, Tukey's HSD test)

Table 8.11: Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Mon

Parameter	0-15 depth				15-30 depth			
	5 years	10 years	15 years	20 years	5 years	10 years	15 years	20 years
pH	4.73±0.05^{a}	4.93±0.06^{a}	4.96±0.09^{ab}	5.22±0.09^{b}	4.58±0.05^{A}	4.90±0.05^{B}	4.63±0.11^{A}	4.93±0.04^{B}
Available N	129.67±4.01^{a}	148.53±3.93^{b}	161.18±4.34b^{c}	173.41±3.65^{c}	80.90±7.15^{A}	84.98±1.70^{A}	81.42±1.83^{A}	92.13±3.03^{A}
Available P	6.45±0.26^{a}	7.24±0.27^{a}	8.21±0.20^{b}	8.53±0.21^{b}	3.48±0.15^{A}	4.12±0.10^{B}	4.37±0.15^{BC}	4.93±0.20^{C}
Available K	65.33±1.73^{ab}	68.56±2.37^{b}	56.22±1.59^{c}	57.12±3.03^{ac}	34.58±2.19^{AB}	39.92±1.62^{A}	33.04±0.62^{B}	35.64±1.51^{AB}
Organic C	2.54±0.06^{a}	2.64±0.05^{a}	2.70±0.03^{a}	2.90±0.05^{b}	1.44±0.04^{A}	1.41±0.04^{A}	1.47±0.04^{A}	1.68±0.03^{B}

Value with same letter have no significant difference (P>0.05, Tukey's HSD test)

Table 8.12: Tukey's HSD test for soil nutrients at different depth across an increasing fallow gradient in Wokha

Parameter	0-15 depth				15-30 depth			
	5 years	10 years	15 years	20 years	5 years	10 years	15 years	20 years
pH	4.67±0.07^{a}	4.80±0.06^{a}	4.83±0.07^{a}	4.91±0.12^{a}	4.53±0.05^{A}	4.80±0.03^{B}	4.62±0.07^{AB}	4.81±0.08^{B}
Available N	153.67±7.47^{a}	173.04±4.87^{a}	205.55±4.09^{b}	215.67±7.73^{b}	105.47±3.94^{A}	121.44±2.90^{A}	148.44±5.22^{B}	148.70±7.59^{B}
Available P	8.19±0.31a	10.15±0.36^{b}	11.35±0.14^{c}	12.25±0.34^{c}	6.73±0.35^{A}	7.08±0.41^{AB}	7.50±0.19^{AB}	8.15±0.19^{B}
Available K	126.00±9.12^{a}	120.00±7.57^{a}	100.32±11.64^{a}	94.00±9.60^{a}	71.37±3.36^{A}	78.06±2.35^{A}	48.05±4.40^{B}	48.33±8.07^{B}
Organic C	2.41±0.04^{a}	3.10±0.13^{b}	3.29±0.10^{b}	3.30±0.05^{b}	1.66±0.03^{A}	1.82±0.04^{AB}	1.93±0.05^{B}	1.70±0.09^{A}

Value with same letter have no significant difference (P>0.05, Tukey's HSD test)

8.4.3 Interaction between soil nutrients and soil depth

In Mizoram, two-way ANOVA result showed significant effect of fallow age (FA) and soil depth (D) on all the soil nutrient parameters (Table 8.13). However, their interaction did not influence the soil pH and organic C in both the districts. It was also observed that the interaction of fallow age and soil depth did not affect the available N and available K in Champhai and available P in Aizawl.

Table 8.13: Two-way ANOVA between soil nutrient parameters and soil depth in Mizoram

Parameter	Factor	df	Champhai		Aizawl	
			F value	P value	F value	P value
pH	Fallow age (FA)	3	22.15	P<0.001	19.74	P<0.001
	Soil depth (D)	1	24.74	P<0.001	18.80	P<0.001
	FA x D	3	1.02	0.389	0.30	0.823
Available N	Fallow age (FA)	3	61.16	P<0.001	155.78	P<0.001
	Soil depth (D)	1	40.21	P<0.001	185.78	P<0.001
	FA x D	3	2.25	0.091	13.19	P<0.001
Available P	Fallow age (FA)	3	7.44	P<0.001	37.43	P<0.001
	Soil depth (D)	1	56.47	P<0.001	23.62	P<0.001
	FA x D	3	3.64	P<0.05	1.68	0.180
Available K	Fallow age (FA)	3	6.68	P<0.001	187.12	P<0.001
	Soil depth (D)	1	77.50	P<0.001	170.03	P<0.001
	FA x D	3	0.87	0.463	12.21	P<0.001
Organic C	Fallow age (FA)	3	3.59	P<0.05	40.56	P<0.001
	Soil depth (D)	1	7.82	P<0.01	46.28	P<0.001
	FA x D	3	0.21	0.889	0.92	0.436

Very poor association of fallow age and soil depth with soil nutrient status was observed in Manipur. The interaction of fallow age and soil depth did not show any influence on the soil nutrient parameters (Table 8.14). However, in Ukhrul, fallow age showed significant effect on the pH, available N, available P and organic C and soil depth had a bearing on the available K. Chandel too experienced a significant effect of fallow age on the available N, available K and organic C while soil depth significantly influence the available P and organic C.

Table 8.14: Two-way ANOVA between soil nutrient parameters and soil depth in Manipur

Parameter	Factor	df	Ukhrul		Chandel	
			F value	P value	F value	P value
pH	Fallow age (FA)	3	10.35	P<0.001	0.298	0.827
	Soil depth (D)	1	0.42	0.518	0.019	0.890
	FA x D	3	0.73	0.536	0.579	0.631
Available N	Fallow age (FA)	3	18.28	P<0.001	8.356	P<0.001
	Soil depth (D)	1	0.36	0.550	2.244	0.139
	FA x D	3	2.85	P<0.05	0.697	0.557
Available P	Fallow age (FA)	3	3.32	P<0.05	0.688	0.563

	Soil depth (D)	1	3.94	0.052	8.736	P<0.01
	FA x D	3	1.21	0.313	1.315	0.277
Available K	Fallow age (FA)	3	1.19	0.321	2.762	P<0.05
	Soil depth (D)	1	13.37	P<0.001	0.715	0.401
	FA x D	3	2.41	0.075	2.081	0.111
Organic C	Fallow age (FA)	3	6.65	P<0.001	13.920	P<0.001
	Soil depth (D)	1	1.45	0.232	162.252	P<0.001
	FA x D	3	0.55	0.651	1.946	0.131

In Nagaland, fallow age and soil depth showed significant influence on all nutrient parameters, however their interaction showed significant effect on available N in Mon and on available P and organic C in Wokha (Table 8.15).

Table 8.15: Two-way ANOVA between soil nutrient parameters and soil depth in Nagaland

Parameter	Factor	df	Mon		Wokha	
			F value	P value	F value	P value
pH	Fallow age (FA)	3	12.663	P<0.001	4.916	P<0.01
	Soil depth (D)	1	15.709	P<0.001	4.816	P<0.05
	FA x D	3	1.721	0.171	0.746	0.528
Available N	Fallow age (FA)	3	15.891	P<0.001	37.570	P<0.001
	Soil depth (D)	1	573.766	P<0.001	189.219	P<0.001
	FA x D	3	7.211	P<0.001	1.015	0.392
Available P	Fallow age (FA)	3	29.516	P<0.001	30.682	P<0.001
	Soil depth (D)	1	575.379	P<0.001	217.262	P<0.001
	FA x D	3	2.060	0.114	7.840	P<0.001
Available K	Fallow age (FA)	3	9.514	P<0.001	7.843	P<0.001
	Soil depth (D)	1	356.203	P<0.001	80.628	P<0.001
	FA x D	3	2.545	0.064	0.292	0.831
Organic C	Fallow age (FA)	3	18.820	P<0.001	23.963	P<0.001
	Soil depth (D)	1	1513.689	P<0.001	582.764	P<0.001
	FA x D	3	1.172	0.327	11.844	P<0.001

8.4.4 Relation of fallow age, soil depth and species abundance with soil nutrient status

The relation of fallow age, soil depth and species abundance with the soil nutrient parameters are presented in the subsequent tables. In Champhai, fallow age and species richness were significantly related to soil pH, available N, organic C while fallow age showed a negative relation with available K. It was also found that soil depth was negatively correlated with available N, P and K. Aizawl, on the other hand, manifested a positive correlation of fallow age and species abundance with all soil nutrient parameters except for available K. A negative relation was also observed between soil depth and soil pH, available N, P, K and organic C (Table 8.16).

Table 8.16: Relation of fallow age, soil depth and species abundance with soil nutrient status in Mizoram

Champhai					
	pH	Available N	Available P	Available K	Organic C
Fallow age	0.541**	0.647**	0.16	-0.342**	0.283*
Soil depth	-0.397	-0.370**	-0.606**	-0.687**	-0.307
Species abundance	0.504**	0.596**	0.154	-0.349	0.279*
Aizawl					
	pH	Available N	Available P	Available K	Organic C
Fallow age	0.577**	0.692**	0.625**	-0.716**	0.674**
Soil depth	-0.363**	-0.496**	-0.339**	-0.452**	-0.444**
Species abundance	0.534**	0.680**	0.609**	-0.684**	0.649**

*Significant at 0.05, **Significant at 0.01

In Ukhrul, fallow age and species abundance were directly related to the pH, available N and organic C content of the soil, while soil depth was negatively related to the available K. Chandel, however, showed a positive relation of fallow age and species abundance with the available N and a negative relation of soil depth with available P and organic C (Table 8.17).

Table 8.17: Relation of fallow age, soil depth and species abundance with soil nutrient status in Manipur

Ukhrul					
	pH	Available N	Available P	Available K	Organic C
Fallow age	0.483**	0.615**	0.144	-0.187	0.366**
Soil depth	-0.066	-0.053	-0.22	-0.389**	-0.129
Species abundance	0.355**	0.616**	0.003	-0.168	0.323**
Chandel					
	pH	Available N	Available P	Available K	Organic C
Fallow age	0.042	0.410**	-0.105	-0.079	-0.129
Soil depth	-0.017	-0.155	-0.333**	-0.095	-0.770**
Species abundance	0.016	0.468**	-0.018	-0.026	-0.098

*Significant at 0.05, **Significant at 0.01

In both the districts of Nagaland, soil depth was found to be negatively correlated with all soil nutrient parameters while species abundance was positively related to pH, available N, P and organic C. In Wokha, fallow age was significantly related to all nutrient parameters and negatively related to available K. In addition, fallow age in (Table 8.18).

Table 8.18: Relation of fallow age, soil depth and species abundance with soil nutrient status in Nagaland

Mon					
	pH	Available N	Available P	Available K	Organic C
Fallow age	0.346**	0.225	0.334**	-0.123	0.172
Soil depth	-0.358**	-0.901**	-0.885**	-0.883**	-0.961**
Species abundance	0.319**	0.373**	0.461**	0.049	0.325**
Wokha					
	pH	Available N	Available P	Available K	Organic C
Fallow age	0.286*	0.504**	0.430**	-0.273*	0.234*
Soil depth	-0.237*	-0.716**	-0.740**	-0.691**	-0.879**
Species abundance	0.235*	0.540**	0.529**	-0.17	0.383**

*Significant at 0.05, **Significant at 0.01

Understanding the responses of species diversity and dominant species to soil nutrient dynamics can enhance our knowledge of species coexistence and the recovery of secondary forests. The difference in soil properties lead to variation in vegetation structure and composition (Chazdon et al., 2007). Plant community features such as plant biomass, vegetation cover, and species composition can be affected due to changes in soil nutrients (Perroni-Ventura et al., 2006), resulting in compositional dissimilarity at the local, landscape, and regional scales. However, there are still many gaps in our knowledge about how soil nutrients affect tree species diversity in tropical forests (Bulenga et al., 2021). Lawrence et al. (2005) reported a positive relation between abundance of species with one or more soil nutrients. Several studies showed significant correlation between species diversity and available P (Long et al., 2018; Bulenga et al., 2021). The findings of Long et al. (2018) further revealed a significant relation of species abundance with available N, P and K. Soil nutrients are therefore likely to play vitally important roles in the successional trajectory and restoration of these tropical coastal secondary forests.

Chapter 9

Conclusion

Spatial and temporal dynamics of shifting cultivation in North-East India based on time-series satellite data

The role of earth-observing satellite images provides the solution for inventory of jhum land because of its wide synoptic coverage in multispectral bands and higher resolution. With the emergence of remote sensing technology, the mapping and monitoring of jhum have been effectively conducted with much validity over time and space. Shifting cultivation landscape is distinguished by spatial pattern of different stages of jhum plots and forests. The use of time series satellite images has made it possible to understand the proportion of land annually cleared for shifting cultivation, cropping and fallow periods, and the spatial distribution of jhum lands. By digitizing the different stages of jhum of each year and performing a post-classification comparison, the crop-fallow rotation cycle/ jhum cycle was assessed. An average area of 56.25 Km^2, 44.42 Km^2, 105.87 Km^2, 80.65 Km^2, 100.81 Km^2 and 45.20 Km^2 of forest is annually slashed for jhum cultivation in Ukhrul, Chandel, Champhai, Aizawl, Mon and Wokha districts respectively. The prevailing jhum cycle in Ukhrul was found to be 10–14 years and 9–13 years in Chandel. Champhai and Aizawl showed lesser jhum cycle years of 9-11 and 7-10 respectively. However, the least prevailing jhum cycle of 5-7 years was found in Mon and Wokha. Therefore, with cropping period of two years, the corresponding fallow period was found to be 8–12 years, 7–11 years, 7-9 years and 5-8 years in Ukhrul, Chandel, Champhai and Aizawl respectively. Mon and Wokha had fallow period duration of 4-7 years. During the study period, increase in population resulted in reduction of jhum size thereby decreasing the total area under jhum and number of jhum plots in the districts. The jhumias of the RD blocks have shifted to smaller land holdings rather than to give up shifting cultivation. And therefore it can be concluded that with increase in population the jhum size decreases without significant increase in the number of jhum plots.

Influence of socio-economic factors on the existing shifting cultivation practice

Although shifting cultivation is criticized at present due to its detrimental effect on the environment, it is still being continued due to its multi-cropping system by ensuring food security and resistance towards pest and disease infection, provide income for the jhumias throughout the year, low cost involved in the process of production and also determines the cultural identity of the tribal communities. Through this study, it was found that among several indicators of socio-economic status, occupation, family size and alternative livelihood practice did not influence the existing jhum practice in Mizoram. Nonetheless, Manipur and Nagaland had all socio-economic parameters contributed certain percent in explaining the variation in the existing jhum practice within the states.

In Mizoram the respondents were aware of the New Land Use Policy (NLUP) introduced by the government of Mizoram. The jhumia's response towards NLUP was not satisfying, as the alternative land-based activities under NLUP involved high investment and the outcome was a long duration, leaving them with no source of income meanwhile. And therefore, there is a need to shift the focus from jhum eradication to upgrading and improving jhum to increase its productivity and livelihood security of jhumias.

Socio-economic vulnerability assessment of jhumias amidst the changing climate in North-East India

In the present study, the socioeconomic vulnerability of jhumias was conducted to assess the magnitude of vulnerability components and dimensions in the jhum prominent districts of Mizoram viz. Aizawl and Champhai, Ukhrul and Chandel in Manipur, and Mon and Wokha in Nagaland. The index values of each indicator in SeVI specify the particular component which is accountable for the emerging vulnerability. Socio-economic Vulnerability Index (SeVI) was found to be highest in Shangshak village in Ukhrul district and Kawlkulh village in Champhai district, while Sesawng in Aizawl district had the lowest SeVI. The current study confirms that jhumia households which fall short to adopt any adaptation strategies to the impacts of climate change were most vulnerable. Exposure to natural hazards was the basic indicator for climate change in the study sites. It was also verified that sole dependence on agriculture made the households highly sensitive to climate variability. In addition, low education, improper resource management, insufficient labour force, poor yield and low income from jhum were some major factors contributing to high vulnerability in the area.

The government of each state have formulated disaster management plan for each district with the aim to create successful and practically reliable communication, genuine and precise database to prepare the public for disaster resilience through capacity building. However, this study calls for policy makers and development planners to invest in education and rural income diversification. Effort should also be made to assess the effect of previous disasters and hazard events so as to come up with obligatory preventive measures and consequently emphasize in adopting new measures for the households to make them less vulnerable henceforth. Contemplating on the aims of Climate-smart agriculture (CSA), several adaptation strategies which integrated the age old traditional knowledge and modern practice were recommended to improve the livelihood status of the jhumias while achieving sustainable food production.

Recovery pattern of vegetation following shifting cultivation

With the decrease in the pristine forests, secondary forests are of greater importance and value in the conservation and restoration of tropical biodiversity. Species richness and basal area recovered relatively with time since abandonment in our study, while the species composition recovery showed resemblance between similar-aged fallows. Topographical factors namely elevation, slope and aspect influenced the high species richness and stem density of fallows. In this study, nine species were identified for active restoration of jhum fallows as these species appear naturally in the forest which colonizes early fallows and continues to grow to mature trees in older fallows. The seedlings of these tree species can be collected from the surrounding forests or germinated and planted in jhum fallows to accelerate natural succession. Tree plantation may be adapted to accelerate the steady process of natural succession in the fallows thereby restoring the species richness and enhancing the carbon sinks. Tropical Amazonia had observed 90% survival in the transplantation of seedlings into fallows with partially established vegetation (Uhl, 1987). This would facilitate quicker rehabilitation and reinstate the soil nutrients making the soil reusable in a short term, such that the expansion of slashing and burning of primary forests for cultivation would be reduced. A gradual increase in the diversity of woody species along the fallow age evinces the potential of longer fallow forests to enhance carbon stock. Further, the results would help in formulating appropriate policy interventions on conservation strategies and developing climate change mitigation policies for efficient preservation of forest carbon stocks.

Soil nutrient status at different stages of succession after abandonment of jhum

Secondary forest succession can be an effective and low-cost strategy to increase forest cover and the associated biodiversity and soil functions. However, little is known about how soil functions develop during succession, and how vegetation attributes influence soil functions, especially in highly biodiverse and fragmented landscapes in the tropics. The study revealed older fallow having high concentration of nutrients. The fallow period and species richness were positively related with soil nutrient parameters whereas soil depth depicted a strong negative relation with the soil nutrient status. The interaction of soil depth and fallow age showed no influence on the soil pH and poor effect on organic C while its interaction had an influence on available N, P and K.

Chapter 10

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Photoplates

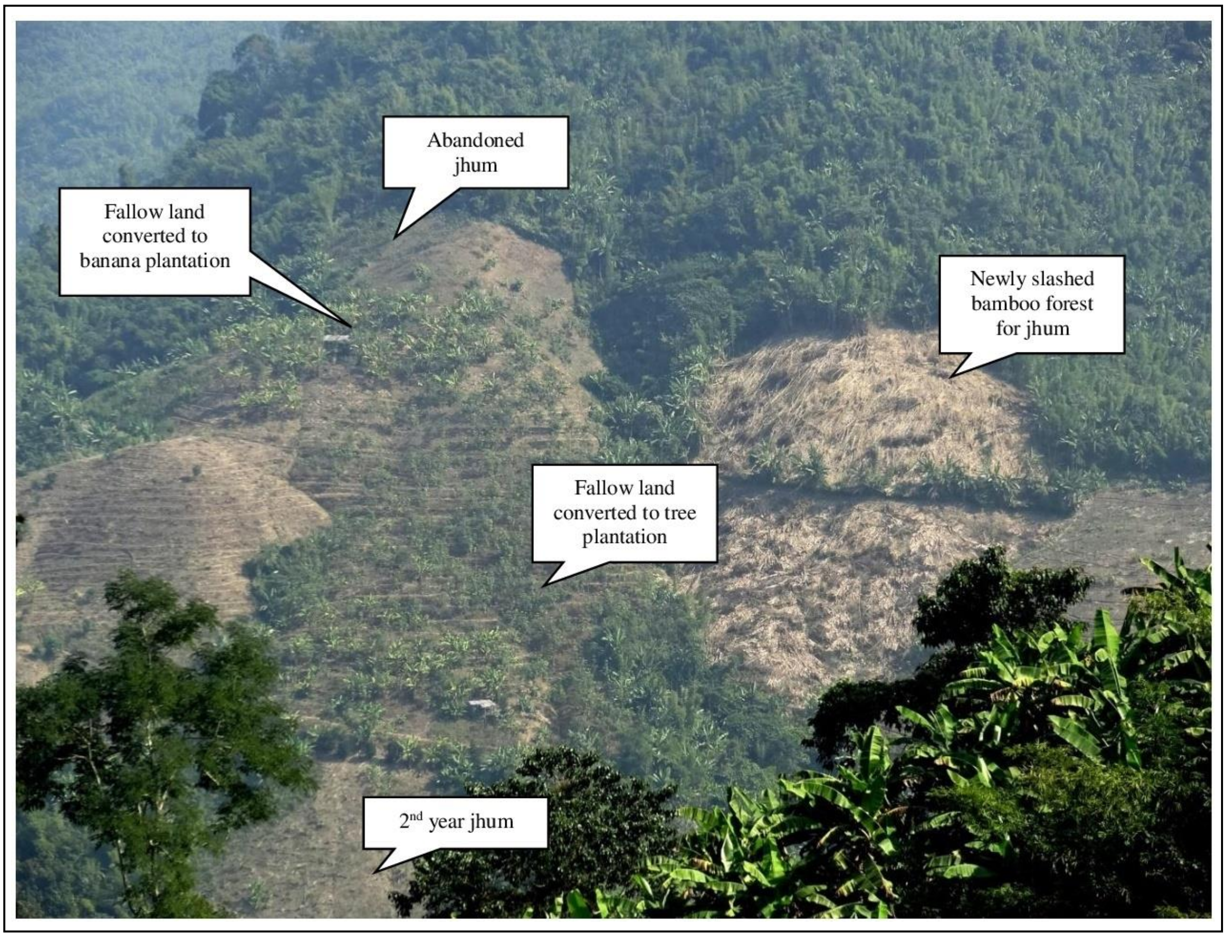

Photo plate 1: Jhum landscape in the study area

Photo plate 2: Socio-economic survey in the villages

Photo plate 3: Vegetation sampling in the jhum fallows

Photo plate 4: Soil sampling in the jhum fallows

BIO-DATA

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Ph.D Topic: Dynamics of shifting cultivation (Jhum) and its impact on the socio-economic conditions of Jhumias, recovery pattern of vegetation and soil in different stages of succession in north-east India.

List of Publication(s)

Sr. No	Title	Journal and page no.	ISSN/ ISBN No.	First/ co-author
1	Recovery pattern of vegetation during succession following slash and burn agriculture in Mizoram, North East India.	Journal of plant biology and soil health. 3(2): 8-16. 2016	ISSN: 2331-8996	First author
2	A geospatial approach to understand the dynamics of shifting cultivation in Champhai district of Mizoram, North-East India.	Journal of Indian Society of Remote Sensing. 46(10): 1713-1723. 2018	ISSN: 0974-3006	First author
3	Assessment of plant diversity at different fallow periods following shifting cultivation in Mizoram, North-East India.	Biodiversity Appraisal, Monitoring and Utilization. (eds) Asha Gupta. pp. 90-102. 2018	ISBN: 978-81-7910-568-9	First author
4	Influence of socio-economic factors on the existing shifting cultivation practice in Champhai district of Mizoram, India	Journal of Hill Agriculture. 9(3): 325-330. 2018	ISSN: 2230-7338	First author
5	Changing trends of Shifting cultivation and its drivers in Champhai, Northeast India	Indian Journal of Hill Farming. 32(1): 1-4. 2018	ISSN: 0970-6429	First author
6	Spatial and temporal dynamics of shifting cultivation in Manipur, Northeast India based on time-seriessatellite data.	Remote Sensing Applications: Societyand Environment. 14: 126-137. 2019	ISSN: 2352-9385	First author
7	Pattern of forest recovery and carbon stock following shifting cultivation in Manipur, North-East India	PlosONE 15(10): e0239906	ISSN: 1932-6203	First author
8	Effect of provenance on morphometric, reproductive and seedling traits of Parkia timoriana (D.C.) Merr in North east India.	Forest Trees and Livelihood. 24(4): 227-239. 2018	ISSN: 1472-8028	Co-author

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10	Characterization of morphometric, reproductive and seedling traits of Parkia timoriana (D.C.) Merr in North east India.	Silva Fennica. 54: 10163. 2020	ISSN: 2242-4075	Co-author
11	Tree species diversity in relation to site quality and homegarden types in North-East India. Agroforestry Systems.	Agroforestry Systems. 96: 187-204 2022	ISSN: 0167-4366	Co-author
12	Oil palm agroforestry enhances crop yield and ecosystem carbon stock in northeast India: Implications for the United Nations sustainable development goals.	Sustainable Production and Consumption. 30: 478-487. 2022	ISSN: 2352-5509	Co-author

Paper(s) communicated

Sr. No	Title with Page nos.	Journal	ISSN/ ISBN No.	First/ co-author
1	Socio-economic vulnerability assessment of shifting cultivators (Jhumias) amidst the changing climate in Mizoram, Northeast India	Applied Geography	ISSN: 0143-6228	First author

Paper(s) presented in Workshop/Seminar

Sr.No	Title of the Paper	Title of the workshop/seminar	Organized by	National or International
1	Assessment of plant diversity at different fallow periods following shifting cultivation in Mizoram, North-East India.	International Conference on Natural Resources Management and Technology Trends	Centre of Advanced Study, Dept. of Life Sc., Manipur University, Imphal & SLNA Planning Dept.Manipur	International
2	Influence of socio-economic factors on the dynamic nature of shifting cultivation in Mizoram	International Conference on Natural Resources Management for Sustainable Development and rural livelihoods	Department of geography and resource management, School of Earth Sciences and Natural Resources Management, Mizoram University	International
3	Dynamics of shifting cultivation in Manipur, India: A Chronosequential study based on Landsat images	Advances in Remote Sensing and GIS Applications	North Eastern Space Applications Centre	National
4	Spatial identification of the crop-fallow rotation cycle in Nagaland	Third National Seminar on Natural Resources Management for Sustainable Development	Department of geography and resource management, MZU and Geography Association of Mizoram	National

Seminars/ Symposia/ Course/ Workshop Attended

Sl. No.	Title of symposium/orientation/tutorial/workshop/ short term course attained	Place	Year
1	Early warning systems for flood	NESAC, Meghalaya	2014
2	Interaction programme for Ph.D. scholars	MZU, Aizawl	2014
3	Research Methodology: Techniques of Data Analysis and Impact Evaluation	SIRD, Meghalaya	2015
4	Basic course on “Remote Sensing, GIS and GNSS”	MZU, Aizawl	2015
5	Pre-symposium tutorial on Watershed Management in Mountainous Landscape	IIRS, Dehradun	2016
6	National symposium on “recent advances in Remote Sensing and GIS with Special Emphasis on Mountain Ecosystem”	IIRS, Dehradun	2016
7	Training programme on “ArcGIS Master Lab Kit”	NERIST, Nirjuli	2016
8	Basic course on “Remote Sensing and GIS Application in Carbon Forestry”	MZU, Aizawl	2017
9	International Conference on Natural Resources Management and Technology Trends	MU, Imphal	2017
10	International conference on Natural Resources Management for Sustainable Development and Rural Livelihoods	MZU, Aizawl	2017
11	Advances on Remote Sensing and GIS Applications	NESAC, Meghalaya	2018
12	Third National seminar on Natural Resources Management for Sustainable Development	MZU, Aizawl	2019

PARTICULARS OF THE CANDIDATE

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DEGREE	:	Ph.D
DEPARTMENT	:	FORESTRY
TITLE OF THESIS	:	DYNAMICS OF SHIFTING CULTIVATION (JHUM) AND ITS IMPACT ON SOCIO-ECONOMIC CONDITIONS OF JHUMIAS, RECOVERY PATTERN OF VEGETATION AND SOIL IN DIFFERENT STAGES OF SUCCESSION IN NORTH-EAST INDIA.
DATE OF ADMISSION	:	05.08.2014
APPROVAL OF RESEARCH PROPOSAL	:	
1. DRC	:	28.04.2015
2. BOS	:	08.05.2015
3. SCHOOL BOARD	:	19.05.2015
MZU REGISTRATION NUMBER	:	7124 of 2014
PhD REGISTRATION NUMBER & DATE	:	MZU/Ph.D/773 of 19.05.2015
EXTENSION (if ANY)	:	18.05.2022

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ABSTRACT

DYNAMICS OF SHIFTING CULTIVATION (JHUM) AND ITS IMPACT ON SOCIO-ECONOMIC CONDITIONS OF JHUMIAS, RECOVERY PATTERN OF VEGETATION AND SOIL IN DIFFERENT STAGES OF SUCCESSION IN NORTH-EAST INDIA

AN ABSTRACT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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ABSTRACT

DYNAMICS OF SHIFTING CULTIVATION (JHUM) AND ITS IMPACT ON SOCIO-ECONOMIC CONDITIONS OF JHUMIAS, RECOVERY PATTERN OF VEGETATION AND SOIL IN DIFFERENT STAGES OF SUCCESSION IN NORTH-EAST INDIA

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Researchers, especially in ecological sciences, have discussed about regional diversity in the practice of jhum cultivation in the North-Eastern States in India. This regional diversity can be regarded as indication of the innovative capacities of these communities. There is, however, very little attempt to study the nature and dynamics of innovative processes of cultivation by these communities (jhumias). The current study attempts to understand the dynamics of shifting cultivation with respect to the socio-economic condition of the jhumias as well as to analyse the recovery pattern of vegetation and soil nutrient status at different stages of succession after abandonment.

With a view to understand the dynamism of shifting cultivation fields in North-East India, the present study was taken up with the following objectives:

1. Spatial and temporal dynamics of shifting cultivation in North-East India based on time-series satellite data
2. Influence of socio-economic factors on the existing trend of shifting cultivation practice
3. Socio-economic vulnerability assessment of shifting cultivators (jhumias) amidst the changing climate in North-East India
4. Recovery pattern of vegetation following shifting cultivation
5. Soil nutrient status at different stages of succession after abandonment of jhum

Spatial and temporal dynamics of shifting cultivation in North-East India based on time-series satellite data

The dynamics of crop-fallow rotation cycles of shifting cultivation has been poorly understood in northeastern part of the country although it is one of the major land use systems in the hilly states of this region. The different cropping stage and abandoned jhum patch of each year's imagery were mapped and post-classified to determine the crop-fallow rotation cycle. An average area of 56.25 Km^2, 44.42 Km^2, 105.87 Km^2, 80.65 Km^2, 100.81 Km^2 and 45.20 Km^2 of forest is annually slashed for jhum cultivation in Ukhrul, Chandel, Champhai, Aizawl, Mon and Wokha districts respectively. The prevailing jhum cycle in Ukhrul was found to be 10–14 years and 9–13 years in Chandel. Champhai and Aizawl showed lesser jhum cycle years of 9-11 and 7-10 respectively. However, the least prevailing jhum cycle of 5-7 years was found in Mon and Wokha. Therefore, with cropping period of two years, the corresponding fallow period was found to be 8–12 years, 7–11 years, 7-9 years and 5-8 years in Ukhrul, Chandel, Champhai and Aizawl respectively. Mon and Wokha had fallow period duration of 4-7 years. During the study period, increase in population resulted in reduction of jhum size thereby decreasing the total area under jhum and number of jhum plots in the districts. The jhumias of the RD blocks have shifted to smaller land holdings rather than to give up shifting cultivation. And therefore it can be concluded that with increase in population the jhum size decreases without significant increase in the number of jhum plots.

Influence of socio-economic factors on the existing trend of shifting cultivation practice

Under this objective, an attempt was made to examine the basic socio-economic situation of the farmers and its relation to the dynamic nature of shifting cultivation on a regional level. Socioeconomic survey was conducted at household level using questionnaires and was then correlated with the existing shifting cultivation practice in the study area. The questionnaire was addressed to obtain particulars on the household description, income and land ownership, land use types, present jhum practice, farmer's perception towards jhum, Government initiatives to control or improve jhum and its economic influence on the farmers. It was found that among several indicators of socio-economic status, occupation, family size and alternative livelihood practice did not influence the existing jhum practice in Mizoram. Nonetheless, Manipur and Nagaland had all socio-economic parameters contributed certain percent in explaining the variation in the existing jhum practice within the states.

In Mizoram the respondents were aware of the New Land Use Policy (NLUP) introduced by the government of Mizoram. The jhumia's response towards NLUP was not satisfying, as the alternative land-based activities under NLUP involved high investment and the outcome was a long duration, leaving them with no source of income meanwhile. And therefore, there is a need to shift the focus from jhum eradication to upgrading and improving jhum to increase its productivity and livelihood security of jhumias.

Socio-economic vulnerability assessment of shifting cultivators (jhumias) amidst the changing climate in North-East India

The present study utilizes household data to examine the Jhumias susceptibility to the changing climate by using the lens of socio-economic vulnerability frameworks. Principle Component Analysis (PCA) was used to select and group the indicators. Varimax rotation was executed on all selected indicators and factors with eigenvalue >1 was incorporated for weight assignment. The index values of each indicator in SeVI specify the particular component which is accountable for the emerging vulnerability. Socio-economic Vulnerability Index (SeVI) was found to be highest in Shangshak village in Ukhrul district and Kawlkulh village in Champhai district, while Sesawng in Aizawl district had the lowest SeVI. The current study confirms that jhumia households which fall short to adopt any adaptation strategies to the impacts of climate change were most vulnerable. Exposure to natural hazards was the basic indicator for climate change in the study sites. It was also verified that sole dependence on agriculture made the households highly sensitive to climate variability. In addition, low education, improper resource management, insufficient labour force, poor yield and low income from jhum were some major factors contributing to high vulnerability in the area.

Recovery pattern of vegetation following shifting cultivation

With the decrease in the pristine forests, secondary forests are of greater importance and value in the conservation and restoration of tropical biodiversity. This chapter is an attempt to determine the forest recovery patterns following shifting cultivation by evaluating the vegetation composition, diversity and abundance with respect to topographical factors. We also used ordination analysis to understand the change in species composition with regard to environmental variables. It was found that species richness and basal area recovered relatively with time since abandonment in our study, while the species composition recovery showed resemblance between similar-aged fallows. Topographical factors namely elevation, slope and aspect influenced the high species richness and stem density of fallows. Furthermore, nine species were identified for active restoration of jhum fallows as these species appear naturally in the forest which colonizes early fallows and continues to grow to mature trees in older fallows. The seedlings of these tree species can be collected from the surrounding forests or germinated and planted in jhum fallows to accelerate natural succession. This would facilitate quicker rehabilitation and reinstate the soil nutrients making the soil reusable in a short term, such that the expansion of slashing and burning of primary forests for cultivation would be reduced.

Soil nutrient status at different stages of succession after abandonment of jhum

Secondary forest succession can be an effective and low-cost strategy to increase forest cover and the associated biodiversity and soil functions. However, little is known about how soil functions develop during succession and how vegetation attributes influence soil functions, especially in highly bio-diverse and fragmented landscapes in the tropics. Under this objective, soil were assessed at two depths and nutrient parameters such as pH of soil, available N, P, K and organic C were determined across an increasing fallow gradient. It was observed that older fallow have high concentration of nutrients. The fallow period and species richness were positively related with soil nutrient parameters whereas soil depth depicted a strong negative relation with every soil nutrient parameters. The interaction of soil depth and fallow age showed no influence on the soil pH and poor effect on organic C while its interaction had an influence on the available N, P and K.