Assessment of shifting cultivation dynamics in East Garo Hills District, Meghalaya, India

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Abstract. Shifting cultivation is an ancient traditional system of cultivation in the slopes of the northeastern region of India, where it is locally known as Jhum cultivation. In these regions, this system of cultivation is at subsistence level. For the study, the area selected is the East Garo Hills district in Meghalaya, one of the states in the region. In the study, a probe is made on the dynamics of parameters, temperature, and rainfall data. The period of study is taken from 1980-2016. Two types of shifting cultivation - current and regenerating shifting cultivation have been distinguished using object-based image analysis. From the study, it is noticed that the area under shifting cultivation is showing an overall decreasing trend. Maximum area under shifting cultivation was mostly found in gentle, strong slopes and mainly at east facing slopes. While moving towards extreme, steep and west facing slopes the area under cultivation was found to be decreasing. The study also reveals more amount of rainfall received there is a decrease in the area of shifting cultivation. Further, a correlation was not being able to establish between temperature and shifting cultivation.

Keywords. Shifting cultivation, temporal satellite data, slope, rainfall and temperature.

1. Introduction

Shifting cultivation is an agricultural system characterized by rotation of fields for a short term. The fields are cultivated for crop production and alternated for a longer period for regeneration (Christanty 1986; Therik 1999; Vongvisouk et. al. 2014). Shifting Cultivation, known as rotational farming, swidden cultivation or slash-and-burn farming is an old form of agricultural system prevailing in the tropics (Rasul and Thapa 2003; Yoshio et. al. 2010; Peng et. al. 2014). In NER, this traditional system of cultivation is commonly known as Jhum system. It is locally known as bun in Meghalaya, zabo system in Nagaland and tila in Tripura and Assam (Spencer 1966; Rahman et. al. 2008). It is also known as or slash-and-burn agriculture. 'Swidden' is an old English term meaning 'burnt clearing'. Shifting cultivation is mainly practiced on hill slopes ranging from gentle sloping land (Craswell et al. 1997; Eastmond and Faust 2006; Kato et al. 1999; Lawrence and Schlesinger 2001; Stromgaard 1992; Thomaz 2009) to steeply sloped regions (Grogan et. al. 2012). Shifting cultivation is found to be the dominant agricultural system in the mountainous regions of Southeast Asia

(SEA), Latin America and Central Africa. In the world, there are about 50 countries (Mertz 2009) and almost 500 million people are directly or indirectly in this traditional system (Goldammer 1988; Sanchez 1996; Kleinman et. al. 1996).

The practice of shifting cultivation in North Eastern Region (NER) of India is practiced on the hill slopes in the whole region, except Sikkim. The practice is associated with the way of life of the tribal communities of the region and is being practiced till the present days. Shifting cultivation method usually begins by selecting a forest patch and clearing the vegetation normally in December and January. Small cut trunks portion and roots are normally not removed and slashed vegetation is allowed to dry up on hill slopes for one to two months or they are burnt in February and March. Ploughing and cultivation of crops begin in April–May, cultivation continues for few years until the soil loses its fertility (Dupin et al. 2009; Fujisaka 1991; Roder et al. 1997; Turkelboom et al. 2008). The site is cultivated for food crops and when the final crop is harvested; the site becomes fallow and is allowed to regain its natural forest cover (Momin 1995; Fujisaka et al. 1996; Tripathi and Barik 2003; Sommer et al. 2004; Vielhauer et al. 2004; Lawrence et al. 2010; Yadav 2013). The cultivators start moving to other virgin areas and repeat the same process (Saikia 2008). After few years, they return back to the former cultivated area and once again start practicing shifting cultivation on it. The people who are involved in shifting cultivation or jhum are known as 'Jhumia'. In Meghalaya, this traditional system involves putting of bushes and crop residues in the form of raised bed (1 m width, 4 m length and 20-25 cm thick) along the slope, covering the bun with 3-5 cm soil. The space between one bun to another is generally kept at 1 m. After covering with soil the plant materials are burnt. Though it is not burnt totally it helps in soil sterilization. Sowing and transplanting are done during April when the first shower starts. The cycle of cultivation, leaving it fallow and coming back to it for cultivation, is called jhum cycle. It is for a period of 3-5 years, which is against the principles of ancient jhum system or conservation agriculture. Food crops like maize, paddy, finger millet, green gram, black gram, rice bean, rajma, tomato, cucurbits, colocasia, sweet potato, ginger, and turmeric are mainly cultivated in the jhum areas. There is an inter-cropping pattern (Rahman et. al. 2008).

Study of shifting cultivation has attracted the attention of many scientists and researchers from different fields (Borthakur 1993). Limited works have been carried out with respect to the spatial distribution of shifting cultivation, which is a diverse and dynamic land use system that is difficult to map. It is often confused with either fallow or scrubland. Assessment of the extent of shifting cultivation on the basis of regional and national sources for nine countries and pattern of changes has been studied (Schmidt-Vogt 2009). Shifting Cultivation is a diverse, complex and dynamic land use. It is difficult to observe, define and measure. The landholding, in this case, is small and therefore difficult to quantify the dynamic and change. An accurate assessment of the scale and pace of changes in shifting cultivation or swidden farming on a regional level is critically important for identifying the processes that account for the dynamics and change, as well as evaluating their consequences, locally and regionally (Padoch 2014). Studies on shifting cultivation carried out earlier before the advents of remote sensing techniques were descriptive or more or less qualitative (Inoue 2000). Remote sensing data with the capability of synoptic coverage, multi-temporal resolution and repetitivity capabilities can provide valuable information on fire events and burned area (Vadrevu and Justice 2011). Making accurate assessment using remote sensing techniques is very challenging (Padoch 2007; Schmidt-Vogt 2009), particularly in mountainous regions (Hurni et al. 2013).

The present study pertains to the dynamics of shifting cultivation in relation to ecological aspects in East Garo Hills district of Meghalaya, India. Using the temporal satellite data (1980 to 2016) and other geophysical data (slope, rainfall and temperature) in the study have helped in understanding the spatial distribution and pattern of shifting cultivation. Correlation of dynamic of shifting cultivation with the change in slope, rainfall and temperature was also studied.

2. Materials and Methods

2.1. Study Site

IOP Conf. Series: Earth and Environmental Science **169** (2018) 012104 doi:10.1088/1755-1315/169/1/012104

East Garo Hills District is one of the districts of Meghalaya in the North-Eastern Region of India and lies between 25°24'36.228"N and 26°0'50.591"N and 90°19'49.822"E and 91°1'55.867"E (Figure 1). The district is bounded by Assam's state to the north, West Khasi Hills District to the east, South Garo Hills District to the south and West Garo Hills District to the West. Subtropical wet hill type of vegetation with evergreen trees is distributed all over the area and in the border areas moist deciduous type of vegetation is found. The area is characterized by hot and humid rainy seasons during the summer, cool and dry during the winter season. Temperature ranges with a minimum average temperature of 21°C to a maximum average temperature of 26.19°C from 1980-2016. The area gets rainfall from the South-West monsoon (Sarma 2003). The area is inhabited by the Garo tribe and livelihood depends on shifting cultivation.

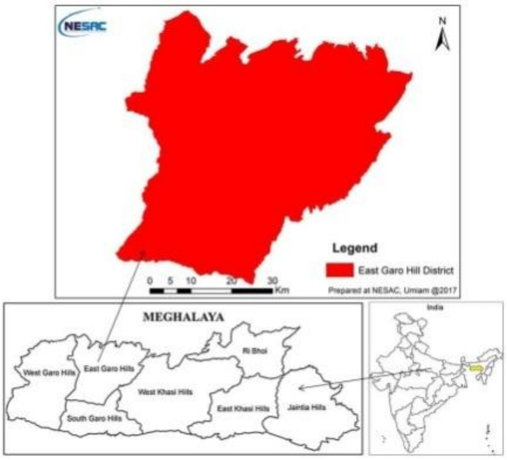


Figure 1: Location of the study area

2.2.Methodology

Data from various sources were analyzed and integrated to understand the spatial distribution and pattern of shifting cultivation identification of factors affecting shifting cultivation. Primary data used in the study include remote sensing satellite data. The time period for analyzing the dynamics of shifting cultivation is 36 years, i.e., 1980-2016. Satellite image of LANDSAT Series and Resourcesat 2 (LISS-III) between 1980 to 2016 were used(Table 1). CartoDEM data was used for deriving slope parameters (height, slope angle and direction) of the study area. For understanding the correlation between dynamics of shifting cultivation and climatic conditions, weather data on temperature and rainfall were analyzed. For the period from 1980 to 2010 weather data were taken from the global weather website. The data is location based (points with latitude and longitude information). For 2016, the weather data was collected from Agriculture Department, Govt. of Meghalaya- website and is based on the location of district headquarters. Average annual temperature and average annual rainfall were taken for analysis. For satellite data processing ERDAS IMAGINE software was used. Digital image classification (segmentation) was carried out using e-Cognition. Change analysis, derivation of slope parameters, integration of data, etc. were carried out in ArcGIS environment. Statistical analysis was done using Microsoft Excel software.

Table 1. Satellite Data used

Data source	Date of acquisition	Resolution (m)
LANDSAT (MSS) Path 147 Row 42	02-02-1980	60
LANDSAT (TM) Path 137 Row 42	07-01-1990	30
LANDSAT (TM) Path 137 Row 42	06-02-1995	30
LANDSAT (TM) Path 137 Row 42	19-01-2000	30
LANDSAT (TM) Path 137 Row 42	05-03-2005	30
LANDSAT (TM) Path 137 Row 42	15-02-2010	30
LANDSAT (OLI/TIR) Path 137 Row 42	08-01-2016	15
CartoDEM	2007	10

On the satellite data, shifting cultivation patches appear in light yellow or greenish tone in color in small, scattered patches, irregular in shape, non-contagious and dispersed and located on hill slopes. These are associated with mountainous/hilly areas mist forest cover and forest cleared areas (NRSA 2005). Two classes of shifting cultivation (Figure 2a) identified in the study are:

i) Current jhum. These are areas that are used for cultivation by the process mentioned above which are clearly predictable on satellite image that is in pre-burnt/post burn condition. On satellite image, current shifting cultivation appears in green color.

ii) Regenerating jhum. These are the areas that were under shifting cultivation, left idle for more than one year but less than 5 years thereby giving a scope for the regeneration of secondary vegetation, especially bamboos or grasses. This category has a tendency to get mixed with forested areas. Areas that are left idle and appear blurry green or very dark green or almost red are classified as regenerating shifting cultivation.

Object-Based Image Analysis approach (eCognition Developer 64 software) was adopted for delineating segments of shifting cultivation areas in images. In case of classes intermixing of shifting cultivation with other land-use classes like wastelands and fallow land, visual interpretation techniques were adopted based on the interpretation element viz., Tone, Texture, Size, Shape, Association and Pattern. Change dynamic analysis was carried out to analyze the dynamics. The pattern of occurrences of current and regenerating jhum areas in different slope conditions wascarried out. The methodology adopted for the study is given in (Figure 2b).

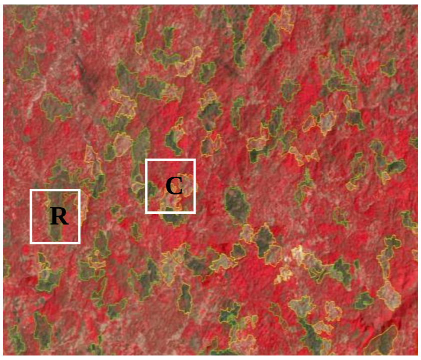


Figure 2a. Illustration of current jhum (**C**) and regenerating jhum (**R**) on the satellite image

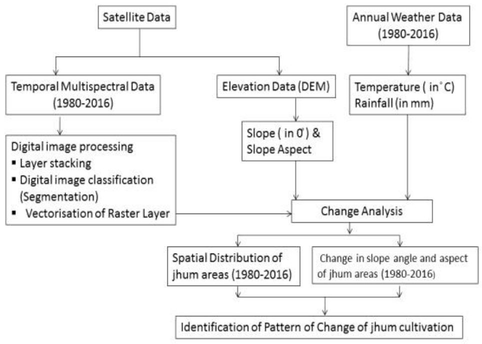


Figure2b. Flowchart of methodology

3. Results and Discussions

3.1. Shifting cultivation change analysis in East Garo Hills Districts, Meghalaya

Shifting cultivation is predominant in East Garo Hills Districts, Meghalaya. Total area under shifting cultivation was 88.33 km^2 in the year 1980 which decreased to 62.3 km^2 in 1990. There is a trend of increase in the area from 74.87 km^2 in the year 1995 to 78.38 km^2 in 2000 and 89.16 km^2 in 2005. The area started decreasing from 47.92 km^2 in 2010 to 39.53 km^2 in 2016 (Figure 3).

The area under current shifting cultivation in East Garo Hills is about 64.75 km^2 in 1980 which decreased to 46.24 km^2 in 1990 and 34.97 km^2 in1995. From the year 2000 to 2005 current shifting cultivation area increase from 46.87 km^2 to 54.08 km^2 but there is a decrease 24.80 km^2 in 2010 to 17.42 km^2. Regenerating shifting cultivation in East Garo Hills was found to be decreasing from 23.58 km^2 in 1980 to 16.06 km^2 in1990. In 1995 the area increased to 39.90 km^2 and decrease to 31.51 in 2000. In 2005, there is an increase to 35.08 km^2. Subsequently, the area decreases in 2010 (23.12 km^2) and in 2016 (22.11 km^2) (Table 2).

There was a pattern of change in shifting cultivation from 1980-2016. Some of the current areas changed to regenerating jhum in the early part of the period, i.e., 1980 to 1990. In some areas non-jhum areas were converted to jhum areas. From 1995 there is a change of regenerating jhum to current jhum areas in some part of the study areas.

Figure 3. Area under shifting cultivation in East Garo Hills District, Meghalaya (1980-2016)

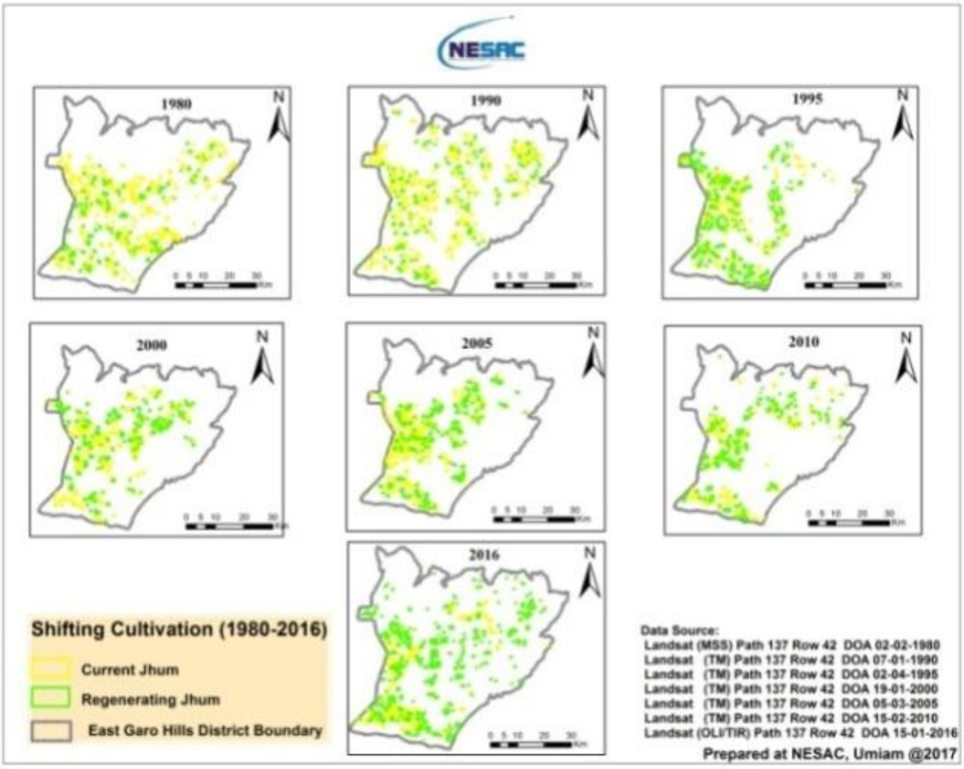
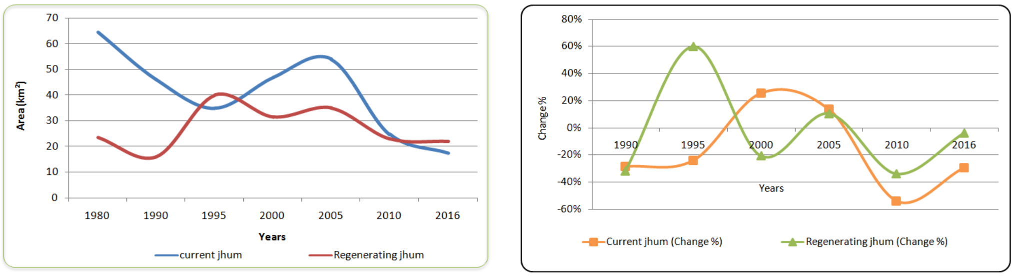


Table 2. Area under shifting cultivation in East Garo Hills District, Meghalaya (1980-2016)

	Shifting cultivation			
Years	**Current jhum (km^2)**	**Current jhum (Change %)**	**Regenerating jhum (km^2)**	**Regenerating jhum (Change %)**
1980	64.75	-	23.58	-
1990	46.24	(-) 28.59%	16.06	(-) 31.91%
1995	34.97	(-) 24.37%	39.90	59.76%
2000	46.87	25.39%	31.51	(-) 21.02%
2005	54.08	13.33%	35.08	10.19%
2010	24.80	(-) 54.14%	23.12	(-) 34.11%
2016	17.42	(-) 29.75%	22.11	(-) 4.35%

In the year 1980-1995, the area under shifting cultivation in the study has shown a decrease in change percentage of current jhum from (-) 28.59% in 1990 to (-) 24.37% in 1995 while under regenerating jhum there was a decrease in change percentage of (-) 31.91% in 1990, whereas, in the year 1995 there was an increase in change percentage of 59.76%. In the year 2000 - 2005, the area under current shifting cultivation has shown an increase in change percentage of 25.39% in 2000 to 13.33% in 2005. Under regenerating jhum there was a different trend where there was a decrease in change percentage of (-) 21.02% in the year 2000 whereas, in the year 2005 there was an increase in change percentage of about 10.19%.While in the year 2010 and 2016 there was a decreasing trend where the area under current shifting cultivation has shown a decrease in change percentage of (-) 54.14% in 2010 to (-) 29.75% in 2016 and under regenerating jhum it has shown a change percentage of (-) 34.11% in 2010 to (-) 4.35% in 2016 (Figure 4).

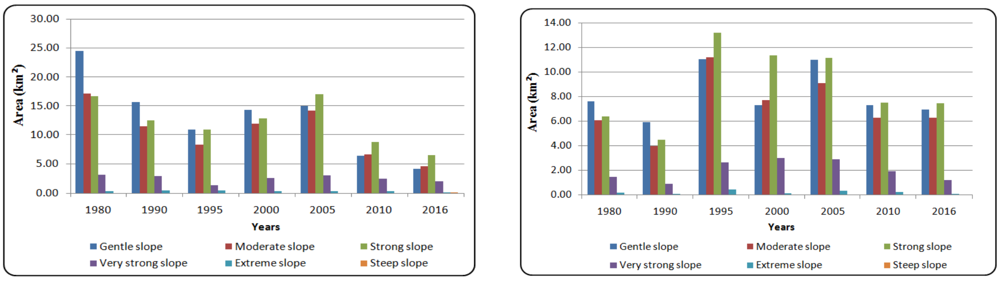


(a) (b)

Figure 4. Graph showing the area (a) and the change percentage (b) which is under shifting cultivation in East Garo Hills District, Meghalaya (1980-2016)

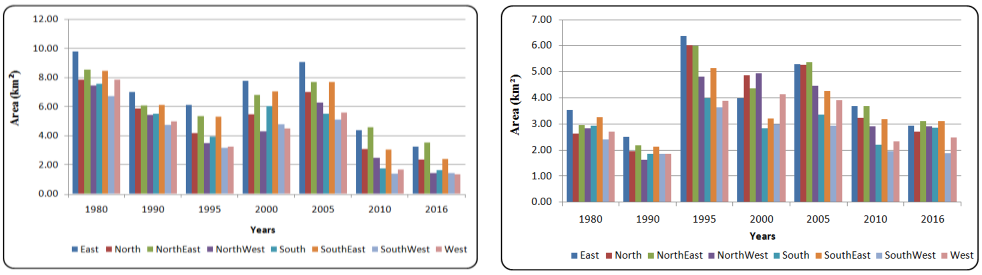
3.2. Shifting cultivation change at different slope and aspect in West Garo Hills District, Meghalaya for 1980-2016

Slope parameters help in understanding the pattern of occurrence of shifting cultivation areas in a region (Fairbridge et al. 1968). In the study area under shifting cultivation are classified according to the areas in which they occur at different slope angle and slope aspect at different time periods. In 1980-1990, the area under shifting cultivation change analyzed at different slope has shown the maximum area under current and regenerating jhum was mainly practice on a gentle slope. In due course of time, the practice of shifting cultivation shifted toward the moderate slope and the steep slopes (Figure 6a and 6b). With regards to the slope aspect, during the period of thirty-six years, the study shows that maximum area under current and regenerating jhum was facing East direction. Other slope directions preferred are northeast and southeast directions (Figure 6a and 6b).



(a) (b)

Figure 5. Graph showing area under current jhum (a) and regenerating jhum (b) at different slope for East Garo Hills District, Meghalaya (1980-2016)



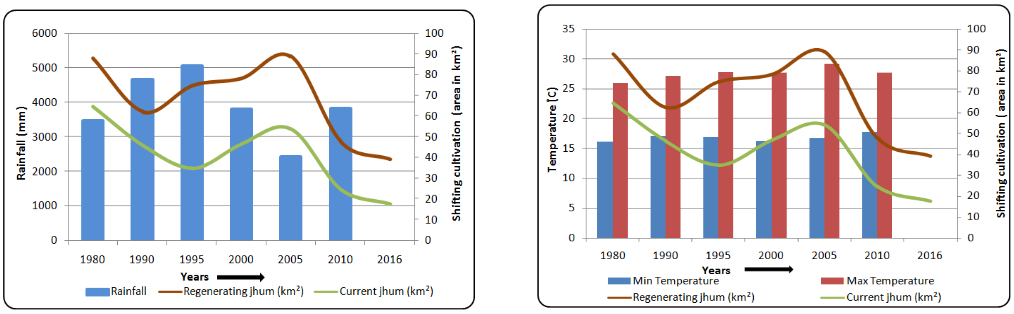
(a) (b)

Figure 6. Graph showing area under current jhum (a) and regenerating jhum (b) at different aspect of East Garo Hills District, Meghalaya (1980-2016)

In the study, attempts have been made to find out the correlation of dynamic of shifting cultivation with rainfall and temperature for the period of thirty-six years. While comparing rainfall with the change of shifting cultivation, it can be pointed out that there more amount of rainfall there is a reduction in shifting cultivation areas (Table 5). A correlation cannot be established between temperature and the dynamic of shifting cultivation in the study area (Figure 7a and 7b).

Table 3. Shifting cultivation in relation to average annual rainfall (mm) and average annual temperature (ºC) in East Garo Hills District, Meghalaya (1980-2016)

Years	**average annual rainfall (mm)**	**average annual temperature (°C)**		**current jhum (km^2)**	**regenerating jhum (km^2)**
		Min.	**Max.**		
1980	3482.18	16.05	25.95	64.75	23.58
1990	4664.53	17.07	27.13	46.24	16.06
1995	5062.65	16.97	27.77	34.97	39.9
2000	3812.76	16.19	27.68	46.87	31.51
2005	2434.48	16.73	29.19	54.08	35.08
2010	3834.28	17.77	27.72	24.8	23.12
2016	N/A	N/A	N/A	17.42	22.11



(a) (b)

Figure 7. Shifting cultivation in relation to average (a) annual rainfall (mm) and (b) average annual temperature (ºC) in East Garo Hills District, Meghalaya (1980-2016)

4. Conclusion

According to the results revealed, it may be concluded that the area under shifting cultivation has decreased in the year 1990. But since 1995-2005 there was an increase in area. Whereas from 2010-2016 the area under shifting cultivation started to decrease once again. It was observed that gentle slope was the most preferred slope for shifting cultivation during 1980-1990 as the maximum area of shifting cultivation was found to be at a gentle slope, but since 1995-2016 strong slope was preferred for shifting cultivation as the maximum area of shifting cultivation was found to have been practiced at a strong slope. East and Northeast facing slopes are mainly preferred for shifting cultivation during the period 1980-2016.

Acknowledgments

This research work is part of the project entitled “Dynamics of Shifting Cultivation in selected districts of North Eastern Region of India- An Ecological and Social Approach. The authors are grateful to the Director, North Eastern Space Applications Centre, for his advice and encouragement in carrying out the project.

References

[1] Borthakur D.N 1983 Shifting cultivation in Northeast India, ICAR, Shillong, Meghalaya pp 1-19

[2] Christanty, L. 1986 Shifting cultivation and tropical soils patterns, problems and possible improvements. In: Marten, G. G., Traditional Agriculture in Southeast Asia: A human Ecology Perspective, West View Press (Boulder, Colorado) pp 229-240
[3] Craswell, E.T., Sajjapongse, A., Howlett, D. J. B. and Dowling, A., J. 1997 Agroforestry in the management of sloping lands in Asia and the Pacific. Agrofor Syst **38** pp 121–137
[4] Dupin, B., de Rouw, A. and Phantahvong, K., B. and Valentin, C., 2009 Assessment of tillage erosion rates on steep slopes in northern Laos. Soil Tillage Res **103** pp 119–126
[5] Eastmond, A. and Faust, B. 2006 Farmers, fires, and forests: a green alternative to shifting cultivation for the conservation of the Maya forest? Land sc Urban Plan **74** pp 267–28
[6] Fairbridge, R. W. 1968 The encyclopedia of geomorphology. Encyclopedia of earth science series. Reinhold Book Corporation, New York **3** pp 1295
[7] Fujisaka, S. 1991 A diagnostic survey of shifting cultivation in northern Laos: targeting research to improve sustainability and productivity. Agrofor Syst **13** pp 95–109
[8] Fujisaka S, Hurtado L, Uribe R 1996 A working classification of slash and burn agricultural systems. Agrofor. Syst. **34** pp 151-169
[9] Goldammer, J.G. 1988 Rural land-use and wildland fires in the tropics. Agrofor. Syst. **6** pp 235–252
[10] Grogan, P., Lalnunmawia, F. and Tripathi, S. K. 2012 Shifting cultivation in steeply sloped regions: a review of management options and research priorities for Mizoram state, Northeast India, Agroforest Syst (2012) **84** pp 163–177
[11] Hurni, K.; Hett, C.; Heinimann, A.; Messerli, P.; Wiesmann, U. 2013 Dynamics of shifting cultivation landscapes in Northern Lao PDR between 2000 and 2009 based on an analysis of MODIS time series and Landsat images. Hum. Ecol. **41** pp 21–36
[12] Inoue, M. 2000 Mechanism of Changes in the Kenyah's Swidden System: Explanation in Terms of Zensification Theory. In Rainforest Ecosystems of East Kalimantan—El Niño, Drought, Fire and Human Impacts; Guhardja, E., Fatawi, M., Sutisna, M., Mori, T., Ohta, S., Eds.; Springer-Verlag: Tokyo, Japan pp 167–184
[13] Kato, M. S. A., Kato, O. R., Denich, M., and Vlek, P. L. G. 1999 Fire-free alternatives to slash-and-burn for shifting cultivation in the eastern Amazon region: the role of fertilizers. Field Crops Research **62** pp 225–237
[14] Kleinman, P.; Bryant, R.B.; Pimentel, D. 1996 Assessing ecological sustainability of slash-and-burn agriculture through soil fertility indicators. Agron. J. **88** pp 122–127
[15] Lawrence, D. and Schlesinger, W. H. 2001 Changes in soil phosphorus during 200 years of shifting cultivation in Indonesia. Ecology **82** pp 2769–2780
[16] Lawrence, D., Radel, C., Tully, K., Schmook, B. & Schneider, L. 2010 Untangling a decline population pressure: The case of Java. Global Environmental Change **9** pp 303–312
[17] Lawrence, D., Radel, C. K., Tully, Schmook, B. & Schneider L. 2010 Untangling a decline on tropical forest resilience: constraints on the sustainability of shifting cultivation across the globe, Biotropica **42** pp 21-30
[18] Mertz, O., 2009 Trends in shifting cultivation and the REDD mechanism. Curr. Opin. Environ. Sustain. **1** pp 156–160

[19] Momin, K. C., 1995Traditional jhum-based economy of the Garos and its changing patterns, In: Hill Societies, Their Modernisation: A Study of North East With Special Reference to Garo Hills. Sangma MS (ed.)-Omsons Publications, New Delhi, India pp 103-109

[20] Padoch, C., Coffey, K., Mertz, O., Leisz, S. J., Fox, J. and & Wadley, R. L. 2014 The Demise of Swidden in Southeast Asia? Local Realities and Regional Ambiguities. Geografisk Tidsskrift, Danish Journal of Geography **107(1)** pp 29-41

[21] Peng L, Zhiming F, Luguang J, Chenhua L, Jinghua Z. 2014 A review of swidden agriculture in Southeast Asia. Remote Sens. **6** pp 1654–1683

[22] Rahman, H., Karuppaiyan, R., Kishore, K., and Denzongpa, R. 2008 Traditional Practices of Ginger Cultivation in Northeast India, Indian Jour. of Traditional Knowledge **8** pp 1, 23-28

[23] Rasul, G., and Thapa, G. B. 2003 Shifting Cultivation in the mountains of South and South East Asia: Regional Patterns and Factors Influencing the Change, Land Degrad. Develop. **14** pp 495-508

[24] Roder, W., Phengchanh, S. and Maniphone, S. 1997 Dynamics of soil and vegetation during crop and fallow period in slash-and-burn fields of northern Laos. Geoderma **76** pp131–144

[25] Saikia, A. 2008 Present status potentials, problems and strategies for agricultural development in North Eastern States. In (Bagchi, K.K, ed) Agricultural Development in NorthEast India- Issues and options, Abhijit Publications, Delhi pp 3-22

[26] Sanchez, P.A. 1996 Alternatives to Slash-and-Burn Agriculture Introduction (Special Issue). Agric. Ecosyst. Environ. **58** pp 1–2

[27] Schmidt-Vogt, D.; Leisz, S.J.; Mertz, O.; Heinimann, A.; Thiha, T.; Messerli, P.; Epprecht, M.; Cu, P.V.; Chi, V.K.; Hardiono, M.; et al. 2009 An assessment of trends in the extent of swidden in southeast Asia. Hum. Ecol. **37** pp 269–280

[28] Sommer, R., Vlek, P. L. G., Sa, T. D. D., Vielhauer, K., Coelho, R. D. R. & Folster H. 2004 Nutrient balance of shifting cultivation by burning or mulching in the Eastern Amazon evidence for subsoil nutrient accumulation, Nutrient Cycling in Agroecosystems **68 (3)** pp 257–271

[29] Spencer, J. E. 1966 Shifting cultivation in south-eastern Asia. University of California Press, Berkeley **19** pp 1-179

[30] Therik, T. 1999 The role of fire in swidden cultivation: a timor case study. In: Russell SJ, Hill GJE, Djoeroemana S, Myers BA (eds) Fire and sustainable agricultural and forestry development in Indonesia and northern Australia. Australian Centre for International Agricultural Research (ACIAR), Canberra pp 77–79

[31] Tripathi, R.S., and Barik, S.K. 2003 Shifting Cultivation in North East India

[32] Turkelboom, F., Poesen, J. and Trebuil, G., 2008. The multiple land degradation effects caused by land-use intensification in tropical steeplands: a catchment study from northern Thailand. Catena **75** pp102–116

[33] Vadrevu, K.P.; Justice, C.O. 2011 Vegetation fires in the Asian region: Satellite observational needs and priorities. Glob. Environ. Res. **15** pp 65–76

[34] Vielhauer, K., Denich, M., Kato, O. R., Socorro, K. M., DeAbreuSá, T. D.& Vlek, P. L. G. 2004 Viability of Mechanized Chop-and-Mulch as Soil Improving Alternative to Manual Slash and Burn Land Preparation, Rural Poverty Reduction through Research for Development. Deutscher tropentag, Berlin

[35] Vongvisouk T, Mertz O, Thongmanivong S, Heinimann A, Phanvilay K., 2014 Shifting cultivation stability and change: contrasting pathways of land use and livelihood change in Laos. Appl Geogr **46** pp 1–10
[36] Yoshio Inouea, Yoshiyuki Kiyono, Hidetoshi Asai, Yukihito Ochiai, Jiaguo Qi, Albert Olioso, Tatsuhiko Shiraiwa, Takeshi Horie, Kazuki Saito, Linkham Dounagsavanh 2010 Assessing land-use and carbon stock in slash-and-burn ecosystems in tropical mountain of Laos based on time-series satellite images, *Intl. Jour. of Applied Earth Observation and Geoinformation* **12** pp 287–297
[37] Yadav, P.K. 2013 Slash-and-burn agriculture in north-east India. Expert opinion on Environmental Biology **2** pp 1
[38] http://globalweather.tamu.edu/ accessed on 2nd December 2016
[39] www.megagriculture.gov.in/PUBLIC/agri_Scenario/ accessed on 22nd December 2016