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.
1. Introduction

(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
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.

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 was carried out. The methodology adopted for the study is given in (Figure 2b).

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 km² in the year 1980 which decreased to 62.3 km² in 1990. There is a trend of increase in the area from 74.87 km² in the year 1995 to 78.38 km² in 2000 and 89.16 km² in 2005. The area started decreasing from 47.92 km² in 2010 to 39.53 km² in 2016 (Figure 3).

The area under current shifting cultivation in East Garo Hills is about 64.75 km² in 1980 which decreased to 46.24 km² in 1990 and 34.97 km² in 1995. From the year 2000 to 2005 current shifting cultivation area increase from 46.87 km² to 54.08 km² but there is a decrease 24.80 km² in 2010 to 17.42 km². Regenerating shifting cultivation in East Garo Hills was found to be decreasing from 23.58 km² in 1980 to 16.06 km² in 1990. In 1995 the area increased to 39.90 km² and decrease to 31.51 in 2000. In 2005, there is an increase to 35.08 km². Subsequently, the area decreases in 2010 (23.12 km²) and in 2016 (22.11 km²) (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)

| Years | Current jhum (km²) | Current jhum (Change %) | Regenerating jhum (km²) | 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).
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).

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 (ºC) | current jhum (km²) | regenerating jhum (km²) |
|-------|-----------------------------|---------------------------------|--------------------|------------------------|
|       |                             | 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                  |

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.

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