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Characterization of jhum fields and fallow cycles in west garo hills district of Meghalaya using remote sensing and GIS techniques

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Abstract
Shifting cultivation is a system of land use involving the slashing and burning of vegetation, few years of cropping followed by a fallow period in which farmers shift to surrounding areas. Shifting cultivation is locally known as jhum in north eastern India, *roca* agriculture in Brazil. Multi-temporal satellite (Landsat) data were used to identify jhum fields and fallow cycles. The current jhum fields of different years were delineated in Arc-GIS and based on imageries of succeeding years, the different jhum field categories were identified. The data were statistically analyzed using Arc-GIS software and areas were calculated using the geometrical calculation function in the attribute tables for all the years. Results revealed that the area under jhum field ranged from 9665.87 ha in 2008 to 22089.55 ha in 2000 with an average area of 15361.76 ha annually under jhum fields during the study period. More first year crop jhum fields were found to cultivate again for second year cropping as compared to earlier years. Jhum cycle of 4-9 year was found to be more prevalent (68.56%) in the district although jhum cycles of 3-16 years were observed. From the study, it was concluded that the synoptic and multi-temporal remote sensing data provided the best technique for identifying different jhum fallow cycles.

Keywords: shifting cultivation, jhum fallow cycles, remote sensing, geographic information system (GIS).

1. Introduction

Shifting cultivation is the first step of agriculture in the transition from food gathering or hunting to food production and believed to have originated in the Neolithic period around 7000 B.C. (Sharma, 1976) [16]. Shifting cultivation is still practiced by tribal communities in many parts of the world particularly in the wet tropical regions (Li *et al.*, 2014) [10] and known by different names such as roca in Brazil, chitimene in Central and Southeast Africa, jhum in India, taungya in Southeast Asia (Fujisaka *et al.*, 1996) [7]. In Northeast India, it is known as jhum, podu in Orissa, kumari in Western Ghats. Shifting cultivation is more traditional and cultural integrated form, ecological and economically viable system of agriculture and jhum cycles are long enough to maintain soil fertility as long as population densities are low (Datta *et al.*, 2014) [3]. It involves the slashing and burning of vegetation and a few years of cropping, followed by a fallow period in which farmers shift to surrounding areas. Forest Survey of India reported 1.73 million ha of forest affected by shifting cultivation in northeast India (FSI, 2000) [6]. National Remote Sensing Centre also reported about 0.76 million ha under shifting cultivation in 2008-09 (NRSC, 2011) [13]. Deb *et al.* (2001) [4] mapped 13.1% areas of East Garo Hills, 9.3% area of West Garo Hills and 4.3% area of South Garo Hills under jhum lands using remote sensing.

Jhuming (Shifting cultivation) is dominantly practiced in the mountainous and hilly parts of the tropical countries like Mexico, Panama, part of South America, Central and South-east Africa, South-east Asia including India, China, Indonesia and other Polynesian islands (Li *et al.*, 2014; Vanvliet *et al.*, 2012) [10, 19]. Deb *et al.* (2001) [4] mapped the jhum lands using remote sensing. The current jhuming in West Garo Hills covered an area of 5685 ha that is 74% of total jhumland and increasing by 9.4% in West Garo Hills. Lallianthanga and Sailo (2013) [9] used Indian Remote Sensing satellite data like Linear Imaging Self-Scanning Sensor-III (LISS-III) and Cartosat-I for studying land use, slope, soil, drainage, etc. of Champhai district, Mizoram. Shifting cultivation occupied 5.89% of total cultivable land. Permanent agricultural/horticultural lands constitute only a fraction of the total land. The land use plan prepared in the study has also considered the conservation of the existing forests including bamboo forests to maintain ecological balance while taking up improved and alternate farming practices and also focuses on finding an alternative to shifting cultivation and identifying land where alternative and productive form of crop production can be adopted as well as are acceptable by the farmers. Yadav *et al.* (2013) [22] studied geospatial modeling to assess geomorphological risk for relentless shifting cultivation in Garo Hills of Meghalaya. They reported that there was decreased in dense forest and open forest during 1991 to 2001 while areas under dense forest and non-forest increased during 2001 to 2010. This increased forest area was confined in the inaccessible high slopes. Shifting cultivation was increased nearly double in high slope and more than double in high altitudinal area during 2001 to 2010 which was negative sign of geomorphological protection. Sarma *et al.* (2015) [15] studied the changing analysis of shifting cultivation in Garo Hills, Meghalaya since 1999 to 2013. The area of abandoned and current shifting cultivation was increased from 19.84 to 48.75 sq. km and 64.18 to 140.73 sq. km, respectively from 1999 to 2009, however, in 2013, the abandoned area decreased to 43.02 sq. km area and current shifting cultivation increased to 158.76 sq. km. More than 70% of shifting cultivation area was concentrated in the moderate and moderately steep slope for all the years.

2. Materials and Methods

West Garo Hills district lies between 89°53' - 90°25' E longitude and 25°12' - 26°0' N latitude and is bounded by the North Garo Hills district on the north east, the East Garo Hills on the east, South Garo Hills on the south east, the Goalpara district =of Assam on the north and west, South West Garo Hills towards south west and Bangladesh on the south. The topography is mostly hilly with plains fringe covering the north, west and south-west borders of Tura, Arbella and Ranggira Mountain. The total area of the district is 2784 sq. km. The area cover under the forest, net sown area, total cropped area and fallow land are about 1650 sq. km (45%), 953.6 sq. km (26%), 1207.4 sq. km. (about 33%) and 12% of the total geographical area respectively as per undivided the district of West Garo Hills. Principal crops grown in the district are rice, maize, millets, oilseeds, pulses and horticultural crops (include orange, pineapple, banana, jackfruit and other citrus fruits). Vegetables are also grown such as potato, sweet potato, ginger, garlic etc. Important plantation crops are arecanut, cashewnut, coconut, tea, black pepper, betel leaf and rubber. Spices like ginger, turmeric, chilli, large cardamom and cinnamon are also grown. Agriculture pattern is mostly multi-cropping cultivation and Jhuming (shifting cultivation). About 20% of the population in the district is dependent on jhum cultivation. About 155.45 sq. km (4.19%) is under jhum cultivation. The jhum cycle has been reduced from >25 years to 3-5 years at present. Such farming may threat to biodiversity and soil conservation and is no longer sustainable (Duguma *et al.*, 2001) [5].

2.1 Soil of the study area

The soil types of West Garo Hills district are mostly red gravelly and red sandy loam in the hilly slopes and clayey loam in the plains. Soils of the hills are moderately deep to deep, loamy skeletal to fine and excessively drained subject to slight to very severe erosion hazards. Soils of hilltops and upper hill slopes are moderately deep-to-deep, fine loamy to fine, excessive drained, subject to very severe erosion hazards and strong stoniness. The soils are acidic in nature and comparatively rich in organic matter and nitrogen but poor in phosphorus.

2.2 Preparation of shifting cultivation area maps

The Landsat data (Landsat 5, 7 and 8) were downloaded from glovis website (www.glovis.usgs.gov) for the path and rows and detailed in Table 1. The data pertained to late February or March for the time period 1999 to 2016 were selected for downloading. This was done since shifting cultivation affected areas were more conspicuous during March. The downloaded data were extracted and layer stacked in ERDAS Imagine software. For the years 2012 and 2013 IRS LISS III data available at NESAC was used since the available Landsat data were not good. The false colour composite (bands 4, 3, 2 for landsat 5 and 7, bands 5, 4, 3 for landsat 8) were used for visual interpretation and onscreen digitization of the jhum fields. The bright patches with regular pattern and dark green colour were delineated as 1st year cropping jhum field once verified with the imagery of the preceding year that there were good signatures of vegetation (forests). Following this procedure, all the 1st year cropping shifting cultivation areas were delineated for the whole of the district. The imagery of the immediate preceding year was again crosschecked for signatures of 1st year cropping shifting cultivation (exposed soil/bright tones) to delineate second year jhum crop for the current (1st) year. This was verified if there were pale green tones (lighter than the signature of the 1st year cropping jhum field of the same year). But if darker pink tone were conspicuous in the previously current shifting cultivation plot, then they are considered as the abandoned jhum fields which are in a fallow stage. So, for each year, the polygons were delineated as 1st year cropping and second year cropping jhum fields. The sum of the 1st year cropping shifting cultivation plot and the second year cropping shifting cultivation plot together will account for total area under shifting cultivation for a particular year. Field ground truths were collected for different jhum categories in the study area. Geo-tagged field photographs were collected for cross checking the interpreted maps and make changes if any discrepancy were observed.

The topological errors in the digitized jhum field polygons were corrected in the Arc GIS for all the years and areas were calculated using the geometrical calculation function in the attribute tables for all the years. The district level vector data of the shifting cultivation for all the year from 2000 to 2016 were then '*unioned*' using the '*overlay*' technique in GIS, and then '*exploded*' to correct the '*multipart polygons*'. With correction of '*multipart polygons*' the planimetry were maintained and the area field was once again calculated to get a correct area for each new polygon. In the attribute table of the above *unioned* layer, SQL queries were run in the '*select by attributes*' tool to select those current shifting cultivation polygons of a particular year with any other year, which will capture the area which were slashed for jhuming after a period of fallow time. These pair-wise comparisons were done starting from the beginning of the study year (2000) and compared with the largest possible year gap (*i.e.* 2016) and subsequently paired with the next possible descending years (2015, 2014…. and so on). This was done in order to avoid the misinterpretation of a possible short jhum cycle for a longer jhum cycle. Likewise pairing was done for the subsequent years, like 2001 paired with 2016, 2015, 2014… and so on and the attributes were updated with the jhum cycle years like 15, 14, 13 as per the year differences between two pair years.

Table 1: Details of data used for the study

Path	Sensor	Row	Year	Date of acquisition of satellite imagery
137	Landsat-5	42	1999	March 05, 1999
137	Landsat-5	42	2000	February 20, 2000
137	Landsat-5	42	2001	February 06, 2001

137	Landsat-5	42	2002	March 05, 2002
137	Landsat-5	42	2003	March 24, 2003
137	Landsat-5	42	2004	March 02, 2004
137	Landsat-5	42	2005	March 13, 2005
137	Landsat-5	42	2006	March 08, 2006
137	Landsat-7	42	2007	March 11, 2007
137	Landsat-7	42	2008	February 26, 2008
137	Landsat-7	42	2009	February 28, 2009
137	Landsat-7	42	2010	February 15, 2010
137	Landsat-7	42	2011	March 06, 2011
109	IRS LISS-III	53	2012	March 29, 2012
109	IRS LISS-III	53	2013	February 28, 2013
137	Landsat-8	42	2014	February 26, 2014
137	Landsat-8	42	2015	March 17, 2015
137	Landsat-8	42	2016	March 19, 2016
137	Landsat-5	43	1999	March 05, 1999
137	Landsat-5	43	2000	February 20, 2000
137	Landsat-5	43	2001	February 22, 2001
137	Landsat-5	43	2002	March 05, 2002
137	Landsat-5	43	2003	March 24, 2003
137	Landsat-5	43	2004	March 02, 2004
137	Landsat-5	43	2005	March 13, 2005
137	Landsat-5	43	2006	March 08, 2006
137	Landsat-7	43	2007	March 11, 2007
137	Landsat-7	43	2008	March 13, 2008
137	Landsat-7	43	2009	March 08, 2009
137	Landsat-7	43	2010	March 11, 20010
137	Landsat-7	43	2011	March 06, 2011
109	IRS LISS-III	54	2012	February 10, 2012
109	IRS LISS-III	54	2013	February 28, 2013
137	Landsat-8	43	2014	March 30, 2014
137	Landsat-8	43	2015	March 17, 2015
137	Landsat-8	43	2016	March 03, 2016

After all the attributes for jhum cycle years were updated, it was exported into. Dbf file format for further processing the data in a spreadsheet. In the spreadsheet, pivot table tool was used for segregate the area under different categories for different years and derived the statistical figures of the different polygon geometries.

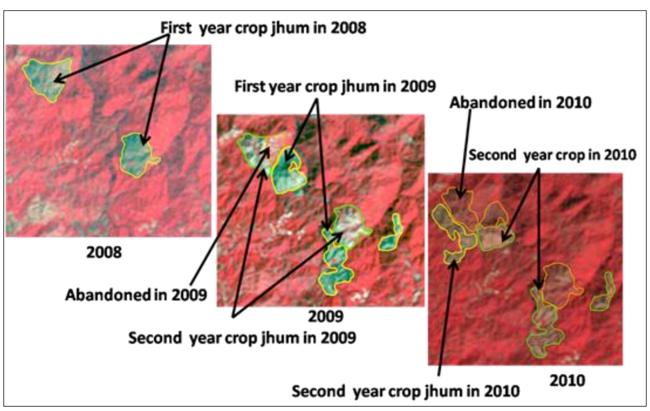

Fig 1: Example of how the jhum fields were identified, delineated and categorized using time series satellite data

2.3 Statistical analysis
The data were statically analyzed using Arc-GIS software and jhum areas were calculated using the geometrical calculation function in the attribute tables for all the years.

3. Results and Discussion
Remote sensing provides synoptic and repeated information which allows retrieval of time-series and reliable information on the spatial distribution of the agricultural systems over large areas (Singh *et al*., 2011; Panigrahy *et al.*, 2005) [18, 14]. Landsat Multi-Spectral Scanner (MSS) or Thematic Mapper (TM) images are useful for crop classification (Badhwar *et al*., 1987) [11]. The remote sensing technique to generate the agricultural statistics (Xiao *et al*., 2003; Liu *et al.*, 2005) [21, 11]. Therefore, in this study, remote sensing and GIS was used to identified and mapping of jhum field and its cycle along with acreage estimations.

3.1 Mapping of jhum fields over the years
The visual interpretation and on-screen digitization techniques were followed for classifying and delineating of jhum fields from the multi-temporal Landsat data of 2000 to 2016. The first and second year crop of jhum maps were delineated and the fallow age of jhum field was determined with time series analysis of satellite data and overlaying techniques. Fig. 2 and Fig. 3 depicts the first and second year jhum crop fields maps of 2000 to 2016. The maximum number of total jhum plots (1041) were observed in 2000 year and minimum in 2013 year (376) (Table 2). The number of jhum fields with first year crop was found high during 2000 to 2004 (402-573) and decreased 2005 onwards till 2016, however, rise up the number (429) in 2011. The maximum number of jhum fields with first year cropping was observed in 2002 year (573) and minimum in 2013 year (131). The number of second year cropping jhum was observed higher (487) in 2000,

442 in 2011, 521 and 438 in 2015 and 2016. The scientist also reported that the jhum farming was an inefficient form of cultivation, none economical production, obsolute technology used, labour intensive and land uneconomically used and yield does not even meet the consumption demand of the cultivating households (Mohanty, 1986; Bohidar, 1973) [12, 2]. Therefore, the overall trend of the 1st and 2ndyear cropping jhum was found reverse and opposite (Fig. 4).

3.2 Acreage estimation of jhuming over the years

The shrinking of land resources and increasing population, the jhuming activity was found 22089.55 ha in 2000 year as maximum following 20842.71 ha in 2014 and 10101.80 ha in 2007 and 9665.87 ha in 2008 as a minimum (Table 3). It was comparatively found the less area coverage under jhum during 2007 to 2010 (10101.80 to 11975.12 ha). The people mindset was also changing from the first year of jhuming towards the second year jhuming in the same land with consideration of population pressure on the existing land. The area under 1st year cropping jhum was more from 2000 (11220 ha) to 2006 (7038.83 ha), declining from 2007 (5226.65 ha) to 2011 (6710.87 ha) and gradually increasing from 2012 (9530.83 ha) to 2015 and 2016 (6788.76 and 6718.14 ha). The result has clearly indicated that second cropping in the same land after first cropping of jhum was practiced in the district. However, the second year cropping practice from 2000 (10869.43 ha) to 2008 (4875.15 ha) was not so much. It was increasing from 2009 (5634.62 ha) till 2015 (12829.54 ha). The possible reason for reducing jhuming areas were lack of labour since jhuming required many labours for cutting and burning of vegetation, jhuming entirely rainfed and risky to crop failure, poor the productivity under shorter fallow cycle and tendency of the young generation to migrate commercial places and government and non-government organization pressurized for settled cultivation to the jhummias. The farmers were still depending upon it either partly or fully for their livelihoods. It ensures staple food for most of the months with rice, vegetables, cash crops, fruits, spices etc. This might be the reason for consideration of jhum farming as one of the best livelihood options in hilly tracts.

3.3 Estimation of area under different jhum cycles

During the study period, it was found 3 to 16 year jhum cycles were observed in West Garo Hills district, however, 4 to 9 year jhum cycle was most prevalent (68.5% of the total overlap area in the district) (Table 4). The maximum area under jhum cycle was observed highest in 5 year (13.6 %), followed by 6 year (11.8 %), 7 year (7.88 %), 4 year (11.25 %) and 8 year (10.5 %). The estimated area under jhum fields was least (0.48 %) in 16 years of jhum cycle, followed by 1.05 % in 15 year, 2.22 % in 14 year, 2.56 % in 13 year jhum cycle. Considering the 2nd year jhum cropping, the jhum fallow of 2-7 years is the most prevalent in West Garo Hills district. Total overlap area under jhum cycles was observed (31104.04 ha) in the district. Many authors also reported the same result the reduction of jhum area and its cycle due to several socio economic reasons and lack of labours (Silva-Forsberg and Fearnside, 1997; Kato *et al*., 1999; Vermeer, 1970) [17, 8, 20]. The acreage of jhum was decreased with increasing the fallow period and minimum was observed as 0.48% in 16 years of fallow period.

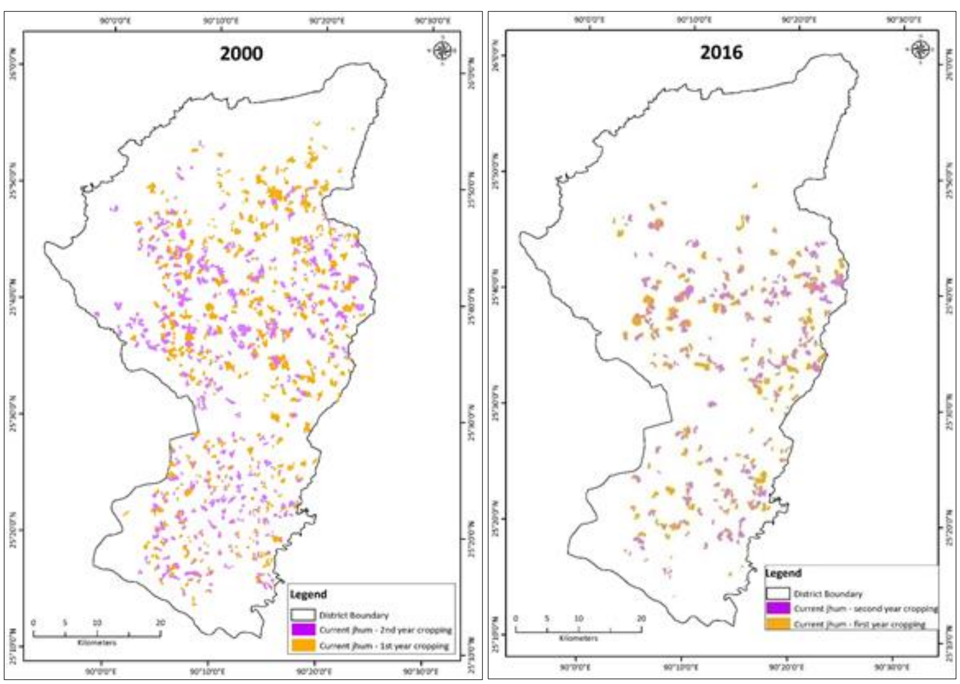

Fig 2: First and second year cropping jhum fields maps of 2000 and 2016

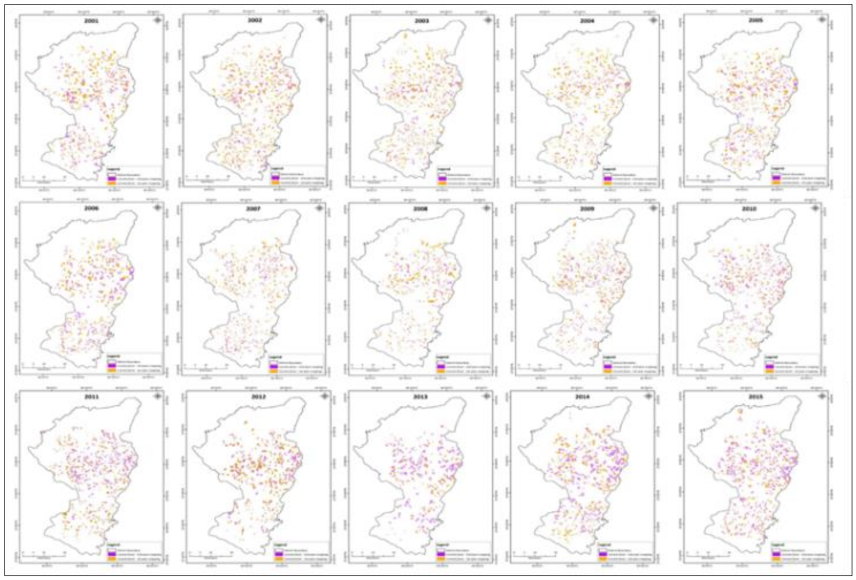

Fig 3: Maps showing area under jhum fields during 2001 to 2015

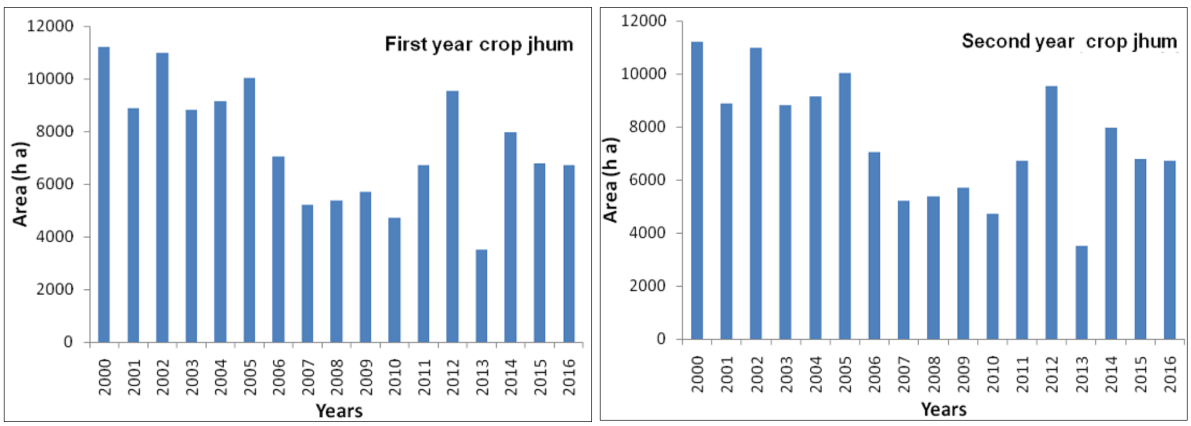

Fig 4: A trend of first and second year cropping jhum of the study area over the year

Table 2: Number of current and second year jhum fields over the years.

Year	No. of 1st year cropping jhum fields	No. of 2nd year jhum fields	Total
2000	554	487	1041
2001	402	277	679
2002	573	339	912
2003	514	349	863
2004	451	248	699
2005	381	352	733
2006	309	261	570
2007	388	351	739
2008	339	255	594
2009	376	361	737
2010	333	393	726
2011	429	442	871
2012	350	307	657
2013	131	245	376
2014	344	372	716
2015	399	521	920
2016	226	438	664

Note: Figures are number of the first and second year cropping jhum area.

Table 3: Acreage estimation of jhuming over the years

Year	1st year cropping jhum (ha)	2nd year cropping jhum (ha)	Total Area (ha)
2000	11220.12	10869.43	22089.55
2001	8875.31	7968.99	16844.31
2002	10986.78	6852.64	17839.42
2003	8819.98	5771.98	14591.96
2004	9150.40	4642.88	13793.29
2005	10027.02	8734.18	18761.20
2006	7038.83	8091.35	15130.18
2007	5226.65	4875.15	10101.80
2008	5383.95	4281.92	9665.87
2009	5708.29	5634.62	11342.91
2010	4735.40	7239.72	11975.12
2011	6710.87	8713.72	15424.58
2012	9530.83	7275.62	16806.45
2013	3500.07	10048.90	13548.96
2014	7957.72	12884.99	20842.71
2015	6788.76	12829.54	19618.30
2016	6718.14	6055.21	12773.35

Table 4: Area under different jhum cycles in West Garo hill district.

Jhum Cycle	Area (ha)	% of total
3 Year	1669.27	5.37
4 Year	3498.56	11.25
5 Year	4092.09	13.16
6 Year	3667	11.79
7 Year	3695.1	11.88
8 Year	3276.46	10.53
9 Year	3094.18	9.95
10 Year	2611.5	8.4
11 year	1943.82	6.25
12 year	1593.76	5.12
13 year	796.58	2.56
14 year	691.67	2.22
15 year	325.79	1.05
16 year	148.26	0.48
Total overlap area	31104.04	
Total non-overlap area	2,47,296.00	

4. Conclusion

The synoptic and multi-temporal remote sensing data provided an improvement in techniques for identifying different jhum cycles. Remote sensing with time series data and GIS techniques helped in accurate and precise analysis of jhum fallow cycles. The total area under jhum in West Garo Hills district was varied from 22089.55 ha (7.9%) in 2000 to 9665.87 ha (3.7 %) in 2008 during the study period with an average of annual area of 15361.76 ha (5.5 %). The area under second year cropping of current jhum has tended to increased as compared to area under first year cropping since 2010, which shows that more farmers tended to crop for second year as compared to earlier. The most prevalent jhum cycle was 4 to 9 years in the West Garo Hills district (68.5%) during the study period.

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