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Impact of Shifting Cultivation on Green Infrastructure: A Remote Sensing Perspective

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ABSTRACT

The study deals with the spatio-temporal dynamics with special reference to shifting cultivation in Nagaland, Northeast India using multi-temporal satellite observation during the last three decades (1987-2017). The study exhibited a significant change in green infrastructure over the temporal scales and highlights the influence of shifting cultivation in the region as evident in the initial decades of observation (1987, 1991, 1996) compared to recent decades barring 2013. The principal component analysis of major vegetation indices highlights a decrease in very high green infrastructure while an increase in very low, moderate, and moderately high green infrastructure (by 69.25%) during 2005-2020 in Nagaland. Although green infrastructure is the most dominant land surface feature (74.25%) in Tuensang district, the large parts were significantly affected due to shifting cultivation (9-17%) and footprint of shifting cultivation as fallow land (29.79% to 30.15%) during 1987-2017. The topographical control was observed on hills with gentle slopes (>15%) with southeastern, south, and southwest aspects for shifting cultivation while an increase was observed in the higher relief. The reduction in the cycle of shifting cultivation and its transformation to permanent intensive agriculture will have a far more negative repercussion on the ecosystem. The study necessitates the incorporation of sustainably managed methods in conjugation with the traditional customs and practices to maintain environmental boundary conditions by means of promotion of agroforestry and tree-based land uses to reshape the adversities of shifting cultivation.

Key words: Vegetation Indices, *Jhum* Cultivation, North East India, Geoinformatics.

INTRODUCTION

Shifting cultivation predominates in tropical nations; more than 6% of tropical forest land has been active under shifting cultivation during 1980-1990 (Singh and Marzoli 1997, Ranjan and Upadhyay 1999). It is a type of primitive subsistence farming technique related to periodically clearing of a forest patch for cultivation and feeding the population till the loss of soil fertility (Cherei 2012). The shifting allows nature to replenish the fertility of the soil through natural regeneration processes (Satapathy et al. 2003**)** and the decrease in the cyclic period of shifting cultivation from 20–30 to 2–3 years resulted in the loss of high-level nutrients, loss of native species, its natural habitat, and its fragmentation (Ranjan and Upadhyay 1999, Deb et al. 2013). Shifting cultivation is the initial phase of agrarian development, which was succeeded progressively by intensive and permanent farming in major parts of the globe (Grigg 1974). Nevertheless, it is still exercised in the highlands in South and South-East Asian nations extensively with different trends and extent (Rasul and Thapa 2003), and a prime factor of deforestation (50%) in the Asian region (Sanchez et al. 2005). It is estimated that around 10 hectares of tribal territory across 16 Indian states are under shift agriculture (Eswaraiah 2003). A large part of shifting cultivation (80.8% of 0.94 m ha) in India is in Northeast states that comprise ~85% of the total arable land (Singh and Singh 1992, Sati 2020). Recent satellite observation reported 1.73 hectares area in Northeastern India has been under influence of shifting agriculture (FSI 2000), which is related to the livelihood of about 4.5 lakh population (MOEF 1997).

Satellite remote sensing is based on reflected or emitted electromagnetic radiation (EMR) and is profoundly used to map the land surface and environment variables in conjugation with effective GIS modelling and analytical tool at spatial and temporal scales (Lillesand and Keifer 1987, Rawat & Kumar 2015). The use of satellite images to understand the dynamics of shifting cultivation is popular (Kamani 2017), which has a significant impact on the local to region ecosystem and climate driver. Various spectral bands-based vegetation indices have been used to identify and monitor the vegetation characteristics and their change over the years. Normalised difference vegetation index (NDVI) is one of the most widely used indexes to monitor and predict agricultural yield, drought assessment, forest fire risk zone mapping and estimation of the relative biomass of vegetation (Rouse 1974, Tucker 1979, Somvanshi and Kumari 2020). It is based on the high reflectance in the red and the NIR channels that are related to the presence of chlorophyll, and internal leaf structure, respectively. Thus, it is used to monitor and modelling of vegetation density, seasonal variation in vegetative vigour and its abundance, leaf area index (Manjunath and Potdar 2004, Mukherjee and Sastri 2004, Ray et al. 2005, Singh et al. 2005, Deosthali and Akmanchi 2006, Kumari and Sarma 2017, Somvanshi and Kumari 2020). To reduce the influence of soil luminance in NDVI as observed in scattered vegetation, soil adjusted vegetation index (SAVI) was introduced with a soil luminance correction factor (Huete 1988, Candiago et al. 2015). Later, the self-correction method for atmospheric effect, the atmospherically resistant vegetation index (ARVI) was adopted to study vegetation density in regions having high aerosol content and atmospherically polluted regions (Kaufman and Tanre 1992, Somvanshi and Kumari 2020). The highly sensitive to chlorophyll concentration, which is related to the proportion of photosynthetically absorbed radiation and linearly correlated with leaf area index (LAI) and biomass, Green normalised difference vegetation index (GNDVI) has been utilized (Gitelson et al. 1996, Hunt et al. 2008, Candiago et al. 2015). The reflectance in the red band is related to the leaf area index but when the LAI exceeds 2, reflectance in the red band does not variably change rather flattens, while the reflectance in the NIR continues to exhibit change (LAI 2-6) in crops. Thus, by extending the spectrum of reflectance of NIR in a new index wide dynamic range vegetation index, the biophysical features of vegetation and terrestrial surface conditions under high biomass was efficiently mapped (Gitelson 2004). The composite analysis of the mentioned indices using the principal component analysis enables the better study of the periodic changes in the vegetation of the region.

While various policy issues and options related to shifting cultivation in Northeast India to increase productivity were also addressed highlighting the intrinsic relationship between the environment, and livelihood (Shiva and Bedi 2002, Maithani 2005). Despite the fact that northeastern India has a rich biodiversity, it is severely affected by extensive deforestation and the continuing traditional practices of shifting cultivation (Goel and Goplakrishna 2000). The age-old practice of shifting cultivation by the Naga people has greatly depleted the natural fertility of the land and denuded the potential forest land (Jamir 2015). A large part of such abandoned area after cultivation turns to grassland/ shrublands and thus align with the concept geo-ecology paradigm through alter the mountain ecosystem, affecting wildlife habitat, global climatic change, biodiversity (Trivedi and Raj 1992, Nigel 1995, Bhaskar 2006). The majority of the hill tribes of the North Eastern Region (NER) in India is predominantly under shifting cultivation primarily along hill slopes, catering to the majority of the Naga communities (Dasgupta et al. 2021). Therefore, in the present study, an attempt has been made to monitor the patterns of shifting cultivation and its impact on green infrastructure together with the control of topographical factors on shifting cultivation.

STUDY AREA

Nagaland state has been selected as the study area, which is in northeast India with an altitude ranging from 800 to 3500m above the main sea level (Fig. 1). The region falls under Eastern Himalayan Agro Climatic Zone with subalpine to sub-tropical climate. The forest cover constitutes 81.21% of the total geographical area of Nagaland (SFR 2009) and is dominated by Moist mixed deciduous, Wet temperate forests, Sub-tropical wet hill, Subtropical pine, and Secondary moist bamboo brakes (Champion and Seth 1968).

DATA AND METHODOLOGY

The LANDSAT and Sentinel 2A satellite Images (http://earthexplorer.usgs.gov) for the years 1987 (TM), 1991 (TM), 1996 (TM), 2002 (ETM+), 2017 (S2A: Copernicus) and LISS III satellite images from the NRSC (http://bhuvan.nrsc.gov.in) for the year 2008, and 2013 (Table 1, Fig. 2). All these satellite

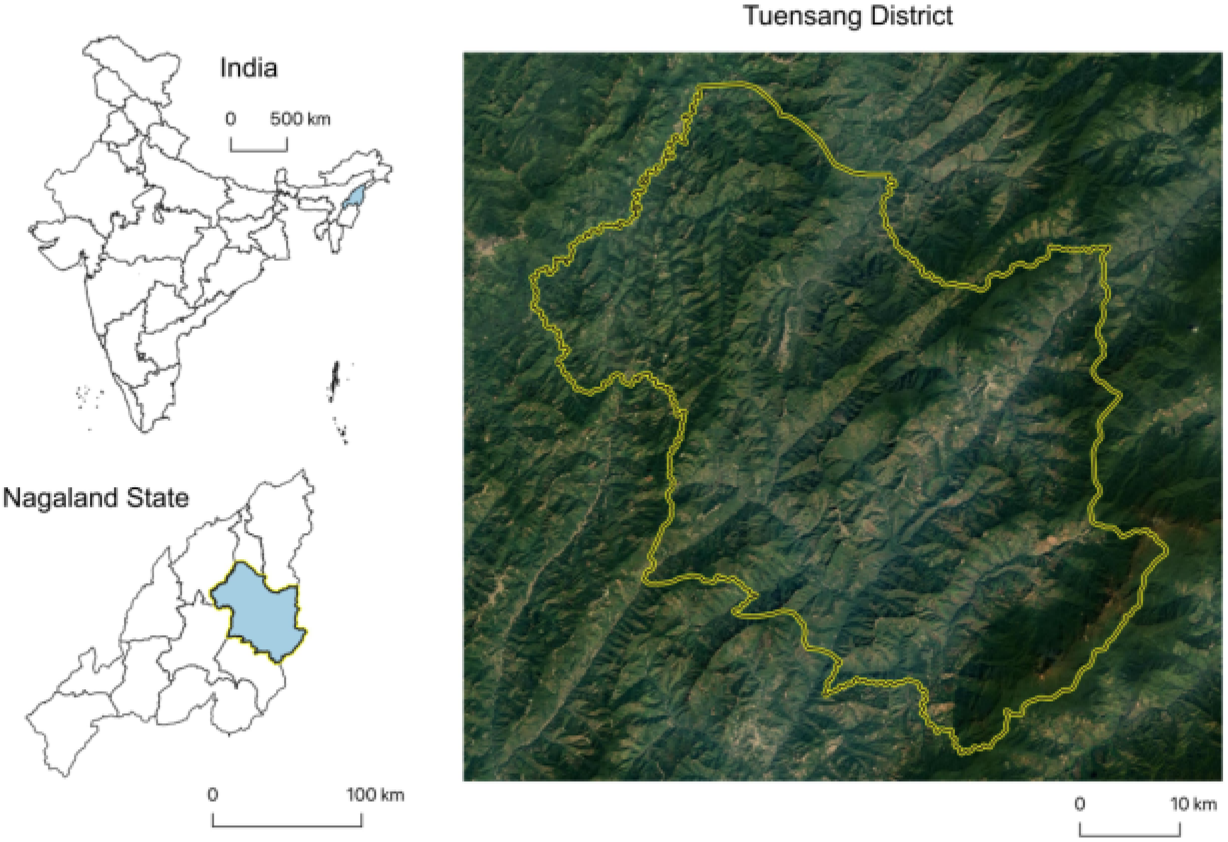

Figure 1. Location map of study area representing Nagaland state and Tuensang district (LANDSAT ™ December 1996), North East India

Table 1. Details of satellite data used in the study

Satellite and sensor	Acquisition Date	Spatial Resolution
Landsat-5 TM	19-12-1987	30 m
Landsat-5 TM	29-11-1991	30m
Landsat-5 TM	11-12-1996	30 m
Landsat-7 ETM	13-12-2002	30 m
LISS-III	29-11-2008	23.5m
LISS-III	31-11-2013	23.5m
Sentinel-2A	1-11-1017	10m
MODIS Aqua	2002, 2010, 2015, 2020	500m

images were acquired during the month of November to January to minimizing the impact of seasonal variation. The random forest classification technique was adopted to classify the region into four classes *viz.*, green infrastructure, and cropland, fallow land, and settlement. The overall classification accuracy and Kappa coefficient for all the observation years was determined, which were ranging from 88.7% to 89.6%, and 0.86 to 0.94, respectively. ASTER GDEM data was used for deriving topographical variables in form of slope, and aspect. The pattern of shifting cultivation was analysed with an aspect map having directions viz., North (N), East (E), South (S), West (W), North-East (NE), South-East (SE), South-West (SW), North-West (NW) to deduce the influence.

The MODIS Aqua (MYD09A1) of spatial resolution 500m was used to study the spatial and periodic variation of vegetation indices, atmospherically resistant vegetation index (ARVI), normalized differential vegetation index (NDVI), soil adjusted vegetation index (SAVI), green normalized differential vegetation index (GNDVI), wide dynamic range vegetation index (WDRVI) and

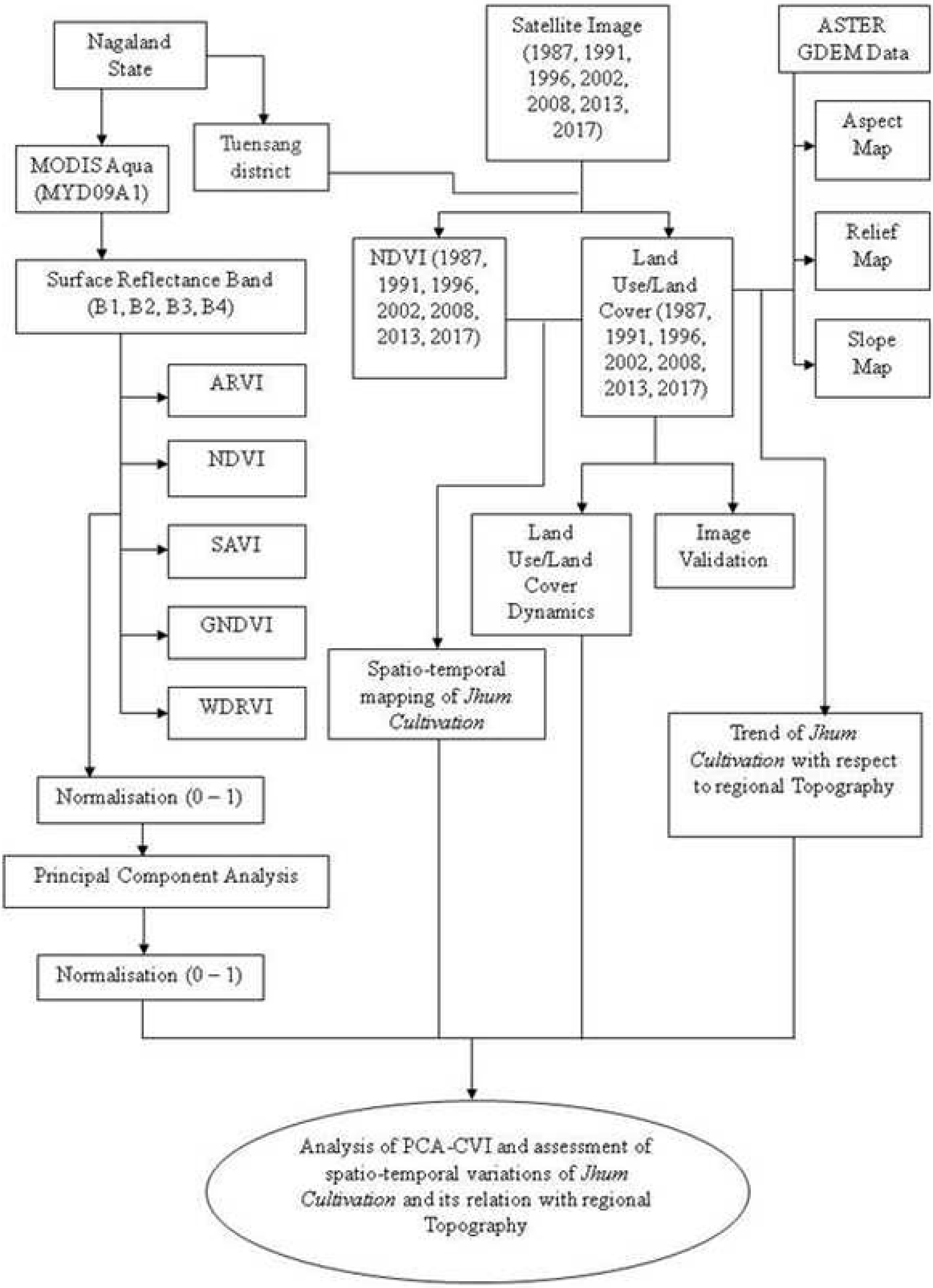

Figure 2. Methodology Flow Chart

composite vegetation index of forest cover of MP using Google Earth Engine, ArcGIS, and MS Excel.

Due to a self-correction process of the atmospheric effect on the red band, ARVI has been used to correct the influence of the atmosphere (Kaufman and Tanre 1992, Somvanshi and Kumari 2020).

ARVI= (NIR-[Red- á(Blue-Red)])/(NIR+[Red- á(Blue-Red)])

Where á = 1 unless the aerosol model is known.

Among the various applications of NDVI, it is used to monitor agricultural yield and estimate biomass production. The high reflectance in the red band indicates the presence of chlorophyll whereas the internal leaf structure results in high reflectance in the NIR band (Rouse 1974, Tucker 1979, Somvanshi and Kumari 2020).

NDVI= (NIR-Red)/(NIR+Red)

SAVI has a soil luminance correction factor (L) which minimizes the influence of soil luminance (Huete 1988, Candiago et al. 2015, Somvanshi and Kumari 2020).

SAVI= ((NIR-Red) (1+L))/((NIR-Red+L))

Where, L = canopy background adjustment factor ranging from (0-1).

GNDVI is highly sensitive to chlorophyll concentration as it is related to the proportion of photosynthetically absorbed radiation and linearly correlated with LAI and biomass (Gitelson et al. 1996, Hunt et al. 2008, Candiago et al. 2015,).

GNDVI= (NIR-Green)/(NIR+Green)

The WDRVI results in better characterization of vegetation biophysical properties and land surface conditions under high biomass situations (Gitelson 2004).

WDRVI= ((a*NIR-Red))/((a*NIR+Red))

Where, a = weighting coefficient and is less than 1. The indicators were normalised from 0 to 1 using the rescale function and further used to generate principal component analysis-composite vegetation index (PCA-CVI). The PCA-CVI is expressed as:

PCA-CVI = f (ARVI, NDVI, SAVI, GNDVI, WDRVI)

The PCA-CVI was normalised such that lower values indicate less density zones and higher values indicate high-density zones of vegetation cover of Nagaland. The PCA-CVI has been analysed for the years 2002, 2010, 2015 and 2020 to study the change in the vegetation cover of Nagaland.

RESULTS

Monitoring Shifting Cultivation Using Vegetation Indices

The spatio-temporal green infrastructure was monitored through vigour concentration using various spectral indices including ARVI, NDVI, SAVI, GNDVI, WDRVI, and later PCA of cumulative vegetation indices (Fig. 3). The ARVI exhibited an increase in area under low ARVI (<0.01) from 3387.75 km^2 (18.12%) to 7115.44 km^2 (38.64%) by 110% during 2005-2020, primarily in northeastern, eastern, southeastern, southern, and southwestern parts of Nagaland indicating the increase in density of green infrastructure (Table 2 and Fig. 4).

While a decrease was recorded in very high ARVI (>0.9; by 55.35%) from 46.06 km^2 (0.25%) to 20.56 km^2 (0.11%). The low NDVI (<0.3) has increased from 3036.75 km^2 (16.25%) to 6679.69 km^2 (35.72%) by 120% during 2005-2020, in contrast, a decrease in the high NDVI (>0.8) by 83.72% from 35.31 km^2 (0.19%) to 5.75 km^2 (0.03%) as observed primarily in northern and northeastern parts of Nagaland. The SAVI exhibited a decrease in area under high SAVI (>0.7; by 34.18%) from 16569.25 km^2 (88.62%) to 10906.19 km^2 (58.33%) as evident in eastern, southeastern, and southern parts of Nagaland. While the area under very low GNDVI (<0.3) increased from 3625.88 km^2 (19.40%) to 7273.25 km^2 (38.9%) in eastern, southeastern, southern, and southwestern parts of Nagaland

Table 2. Area (%) statistics under different classes of vegetation indices in Nagaland during 2005-2020

Class	**ARVI**				**NDVI**				**SAVI**				**GNDVI**				**WRDVI**				**PCA-CVI**			
	2005	**2010**	**2015**	**2020**	**2005**	**2010**	**2015**	**2020**	**2005**	**2010**	**2015**	**2020**	**2005**	**2010**	**2015**	**2020**	**2005**	**2010**	**2015**	**2020**	**2005**	**2010**	**2015**	**2020**
<0	18.12	17.11	34.40	38.64	0.03	0.01	0.07	1.58	0.00	0.01	0.07	1.58	0.03	0.01	0.06	1.60	0.03	0.01	0.07	1.58	27.59	38.58	47.07	46.70
0 - 0.1	8.32	5.67	7.62	6.23	0.19	0.60	1.94	2.68	0.00	0.06	0.27	0.48	0.25	0.75	2.46	3.40	0.19	0.60	1.94	2.68	18.98	6.54	4.46	5.02
0.1 - 0.2	10.68	6.79	7.46	5.90	3.29	5.04	11.60	13.16	0.00	0.55	1.67	2.20	3.82	5.41	13.06	14.68	3.29	5.04	11.60	13.16	8.01	5.38	3.17	2.61
0.2 - 0.3	11.87	8.82	7.23	5.52	12.74	10.43	16.44	18.30	0.15	1.65	4.65	5.15	15.28	10.79	18.18	19.22	12.74	10.43	16.44	18.30	4.24	4.33	3.13	2.57
0.3 - 0.4	11.97	11.58	7.25	5.68	20.55	17.88	17.72	14.72	0.65	3.38	6.95	8.01	25.92	17.75	18.47	14.63	20.55	17.88	17.72	14.72	4.50	4.83	3.97	3.11
0.4 - 0.5	11.92	13.57	7.83	7.14	24.03	25.34	17.12	12.93	1.94	4.62	7.86	9.25	26.59	29.19	17.50	13.76	24.03	25.34	17.12	12.93	5.55	5.92	4.41	3.91
0.5 - 0.6	10.12	13.77	8.67	8.39	21.72	26.31	16.72	13.47	3.36	5.81	8.58	9.05	19.08	29.72	19.00	17.04	21.72	26.31	16.72	13.47	6.84	7.50	5.75	4.67
0.6 - 0.7	6.62	13.69	8.82	8.78	12.79	14.10	13.63	15.47	5.28	7.93	8.76	8.01	8.46	6.30	10.65	15.15	12.79	14.10	13.63	15.47	7.85	9.25	7.67	6.46
0.7 - 0.8	7.36	7.62	8.53	10.24	4.48	0.30	4.69	7.65	8.16	9.95	8.97	6.71	0.55	0.07	0.62	0.52	4.48	0.30	4.69	7.65	7.68	10.70	9.45	9.60
0.8 - 0.9	2.79	1.20	2.03	3.37	0.19	0.00	0.07	0.03	11.00	12.02	8.54	6.52	0.00	0.00	0.00	0.00	0.19	0.00	0.07	0.03	6.62	6.54	9.53	11.75
>0.9	0.25	0.19	0.17	0.11	0.00	0.00	0.00	0.00	69.45	54.09	44.02	45.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.12	0.44	1.39	3.60

whereas the high GNDVI (0.6-0.7) from 1582.63 km^2 (8.46%) to 2832.75 km^2 (15.15%) in Northern parts on Nagaland. The WDRVI exhibited a decrease in values in eastern, southeastern, southern, and southwestern parts of Nagaland and an increase in Northern parts of Nagaland. The PCA-CVI indicates a decrease in very high values while an increase in very low, moderate, and moderately high values (by 69.25%) during 2005-2020 in Nagaland. Similarly, the very low values have increased in the southern parts of Nagaland.

Spatio Temporal Monitoring of Shifting Cultivation in Tuensang District

The multi-temporal multi-resolution satellite-based LULC mapping exhibited significant changes in patterns of shifting cultivation followed by fallow land and green infrastructure in Tuensang district during 1987-2017 (Figs. 5 and 6a). The green infrastructure was one most dominant land use/ land cover (74.25% of the district) during 1991, which decreased to 63.34% in 2017. The area under shifting cultivation varies from 9% to 17% during 1987-2017. While the built-up land was very nominal (0.62%) in terms of area coverage during 1987, and experienced a slight increase (0.82%) by 2017.

The fallow land as the footprint of shifting cultivation was a dominant phenomenon in the district, which observed a minor increase (29.79% to 30.15%) during 1987-2017. To discriminate between patches of shifting cultivation and permanent bare land including continuously cultivated fields, the patches with a low NDVI value throughout three decades (1987 to 2017), were considered as bare land. Episodic variations in shifting cultivation were observed in the Tuensang district as high during 1987 (280.1 km^2), very high during 1991 (316.43 km^2), moderate during 1996 (209.01 km^2), low during 2002 (189.87 km^2), 2008 (191.63 km^2), extremely high during 2013 (376.3 km^2), and very low during 2017 (107.82 km^2). The LULC changes analysis exhibited an overall decrease in shifting cultivation (-61.50% change) during 1987-2017, while an increase in green infrastructure (12.83%) and fallow land (2.41%) (Table 3).

Table 3. LULC Change (%) from 1987-1996, 1996-2008 and 2008-2017.

Land Surface features	**Change (%)**		
	1987-1996	**1996-2008**	**2008-2017**
Green Infrastructure	17.92	-2.80	-1.5
Shifting cultivation	-25.38	-8.31	-43.73
Settlement	61.20	7.60	21.05
Fallow land	-22.6	11.43	18.77

The NDVI based assessment supplements the spatio-temporal analysis of land under shifting cultivation. The significant change in green infrastructure over the temporal scales highlights the active influence of shifting cultivation as evident in the initial decade of observation (1987, 1991, 1996) compared to recent decades barring 2013 (Fig. 5).

ASTER Global Digital elevation model (GDEM) based slope analysis exhibited the preference of gentle slopes (>15%) as compared to steep slopes (30–45%) in the Tuensang district. While the southeastern, south, and southwest aspects of Naga hills were preferred for shifting cultivation followed by the west, east and northeast, while least in the northwest barring 2013 and north aspects (Figure 6b). A shift in cultivation plots towards higher elevations was noted over the years. The recurrent frequency of shifting cultivation in the same geographic location was analysed over the three decades that

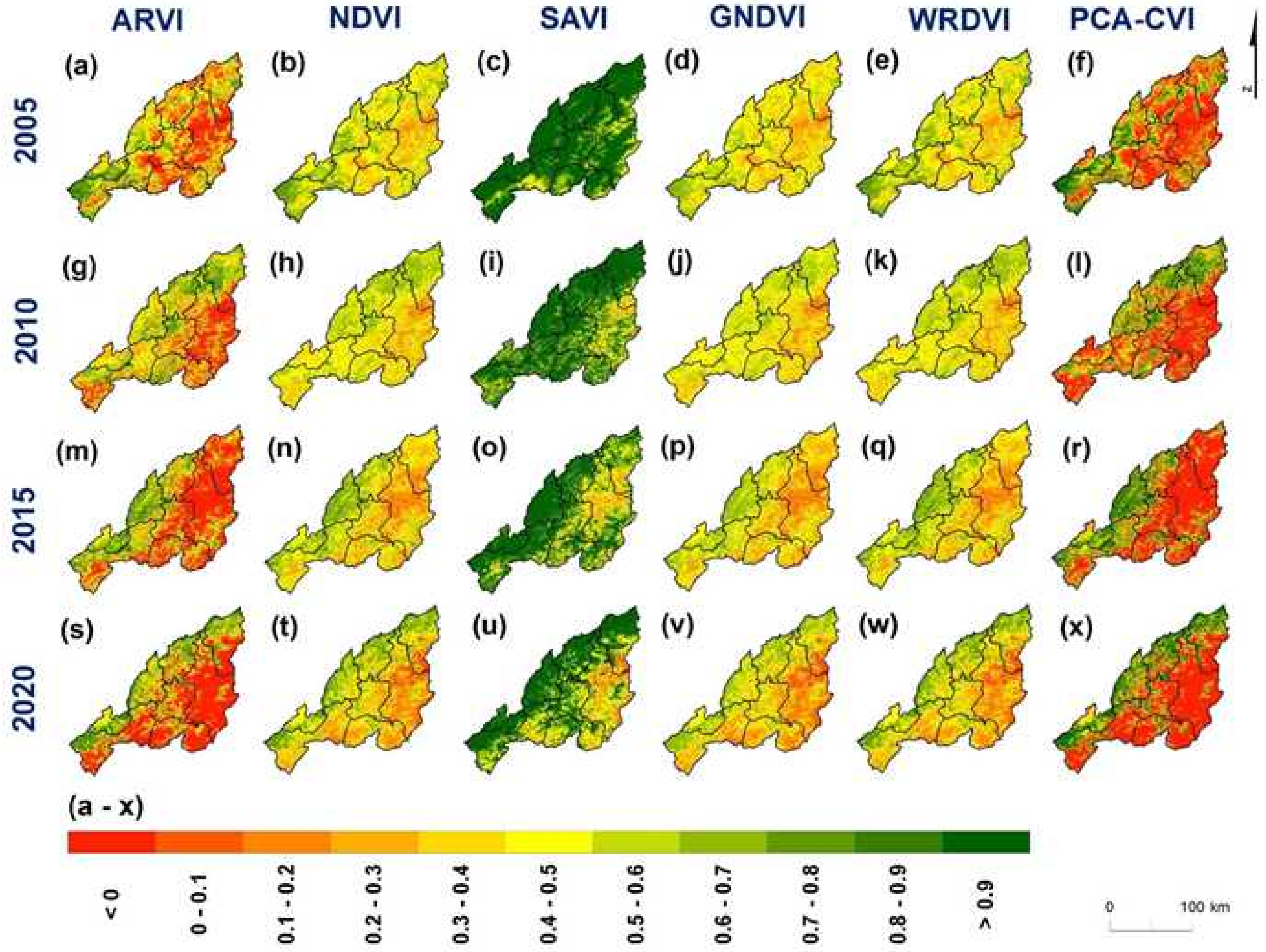

Figure 3. ARVI, NDVI, SAVI, GNDVI, WRDVI and PCA-CVI of Nagaland state for the years (a-f) 2005, (g-l) 2010, (m-r) 2015, and (s-x) 2020

exhibited that central hills and southern parts were predominantly used for shifting cultivation Tuensang (Figure 7-k).

DISCUSSION

The spatio-temporal monitoring of shifting cultivation through various vegetation indices (2005-2020) and land surface mapping (1997-2017) exhibited the variability in the patterns of shifting cultivation with an overall decrease under the active area under cultivation with episodic variations. Although it has a wide impact on the existing green infrastructure of the region. The PCA of the composite of major vegetation indices exhibited a decrease in very high green infrastructure regions while an increase in very low, moderate, and moderately high green infrastructure (by 69.25%) during 2005-2020 in Nagaland. Although green infrastructure is the most dominant land surface feature (74.25%) in Tuensang district, the large parts were significantly affected due to shifting cultivation (9-17%) and footprint of shifting cultivation as fallow land (29.79% to 30.15%) during 1987-2017. The vegetation indices-based assessment supplements the spatio-temporal analysis of land under shifting cultivation. The significant change in green infrastructure over the temporal scales highlights the active influence of shifting cultivation as evident in the initial decade of observation (1987, 1991, 1996) compared to recent decades barring 2013 (Fig. 5). The shifting cultivation is primarily dependent upon anthropogenic activities followed by precipitation and various factors.

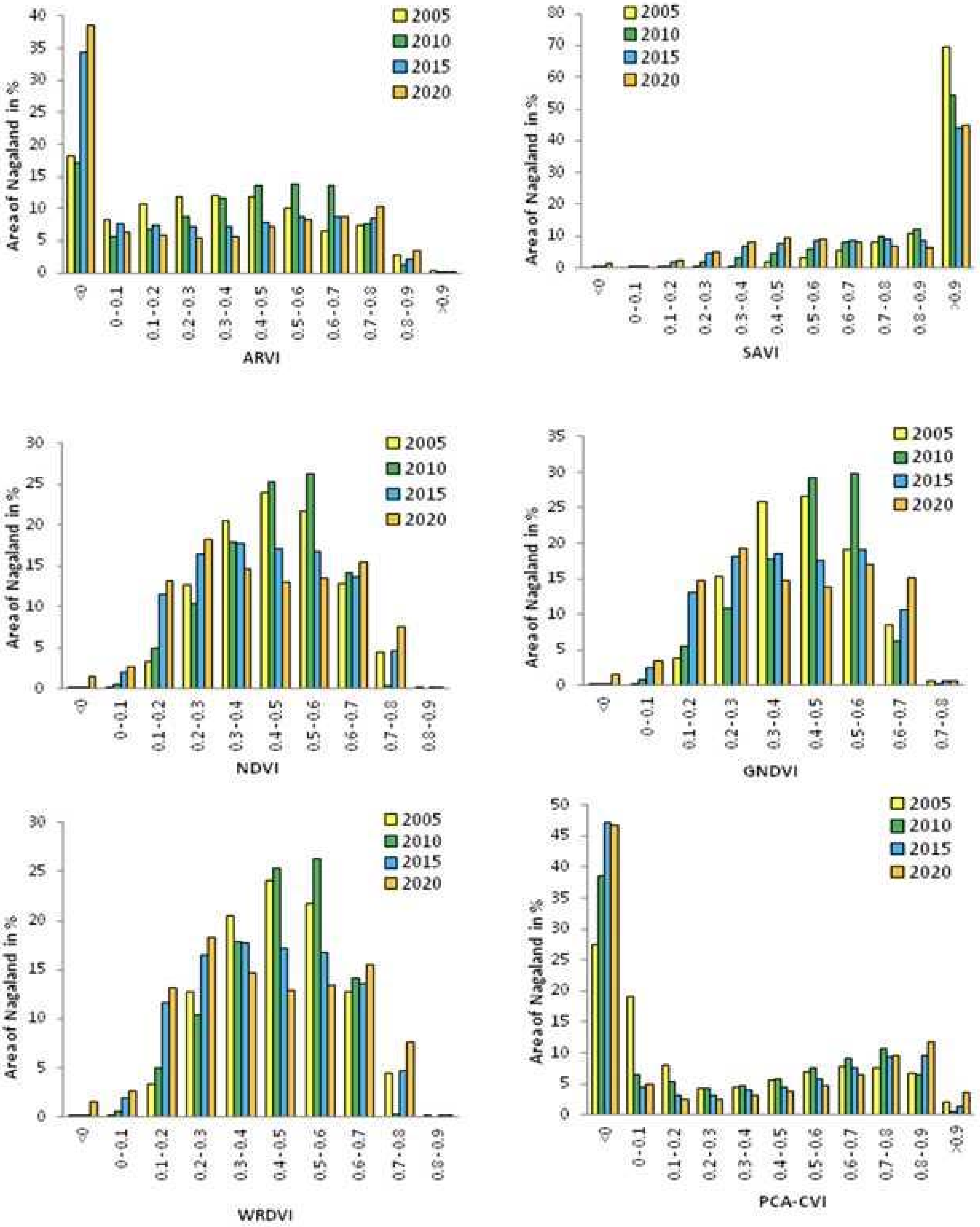

Figure 4. The area under various categories of indices (a) ARVI, (b) NDVI, (c) SAVI, (d) GNDVI, (e) WRDVI and (f) PCA-CVI of Nagaland state for the years 2005-2020

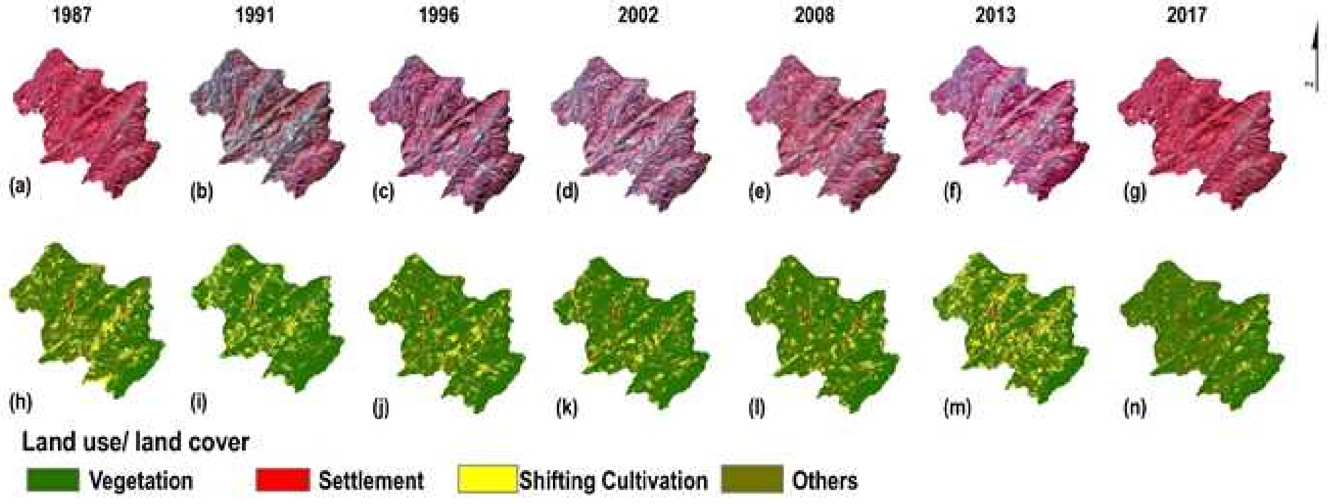

Figure 5. Spatio-temporal (a-g) FCC of satellite images, (h-n) LULC in Tuensang, Nagaland during 1987-2017

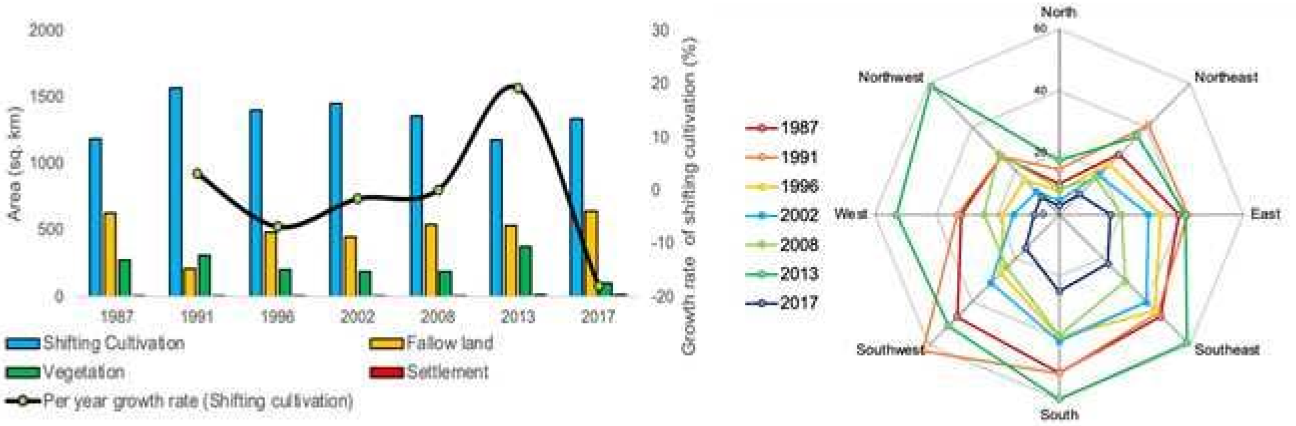

Figure 6. (a) Annual variation of shifting cultivation and (b) radar diagram representing topographical aspects of shifting cultivation in Tuensang district during 1987-2017

The topographical analysis showed that the hills with gentle slopes are predominantly used for shifting agriculture due to ease in agriculture activity, high water retention, and more soil depth. While the southeastern, south, and southwest aspects of Naga hills were preferred for shifting cultivation due to comparatively warmer than northern and eastern aspects. Also, the southern aspects were mostly occupied by tribal communities in the Tuensang district, who predominantly practiced shifting cultivation. Also, an increase of shifting cultivation practices was observed towards higher elevation in the recent decades due to increasing demand and larger converge. The recurrent frequency of shifting cultivation in the same geographic location was analysed over the three decades that exhibited that central hills and southern parts were predominantly used for shifting cultivation Tuensang (Fig. 7-k).

While the repeat cycle of shifting cultivation practices was primarily observed once to thrice in the large parts in the last three decades while the >6 times were observed in very smaller parts as farmers mostly adopted a practice of 10 years fallow period to ameliorate soil fertility (Teegalapalli et al. 2018). The cycle of shifting cultivation has been reduced from 25–30 years to 2–3 years in the recent past years

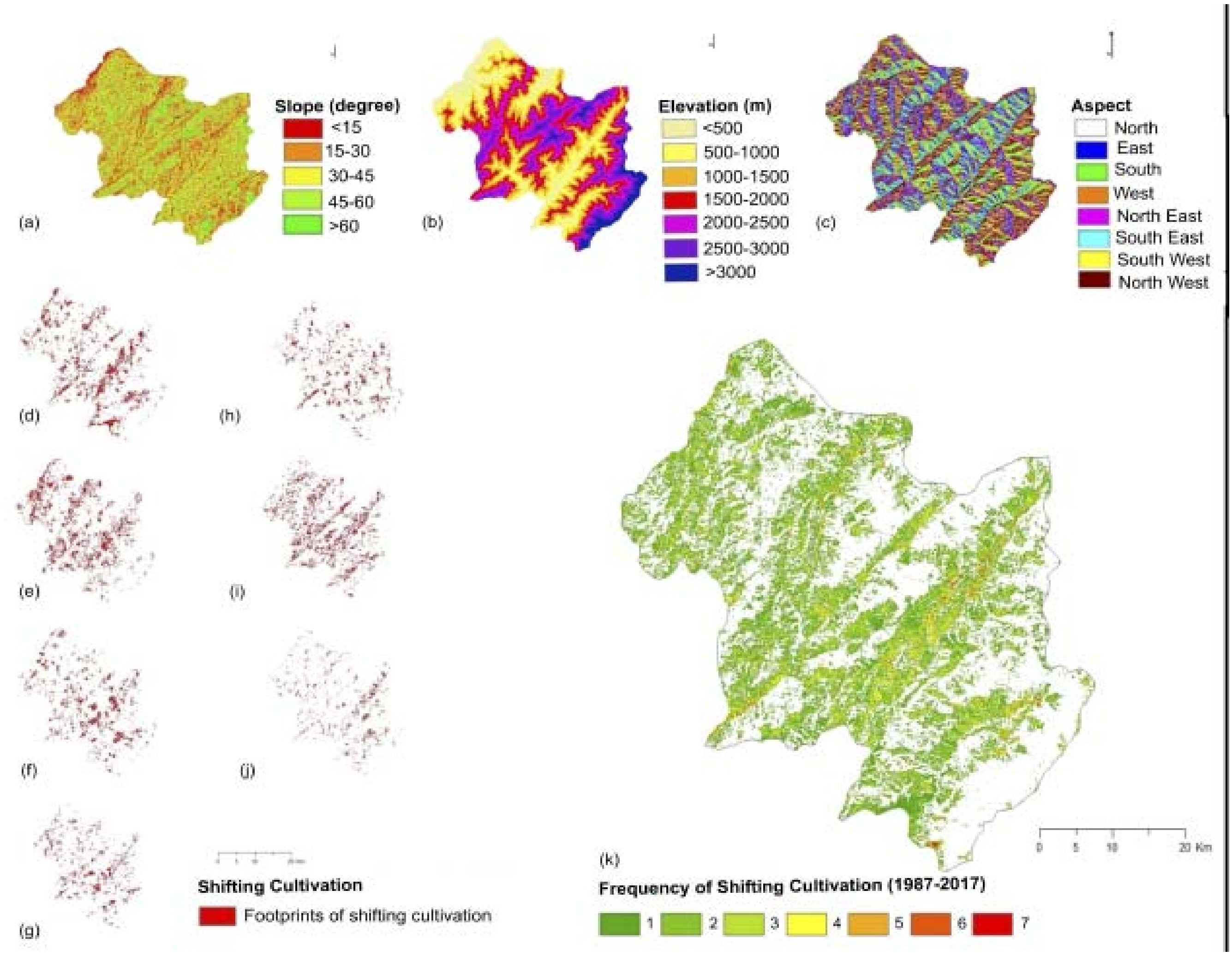

Figure 7. Topographical control of shifting cultivation (a) slope, (b) elevation, (c) aspect, and (d-g) frequency of shifting cultivation and (k) its cumulative impact in Tuensang district during 1987-2017.

due to an increase in population and food demand, and deterioration of the resilience of green infrastructure (Patro and Panda 1994, Ranjan and Upadhyay 1999, Sati 2020). Previous studies suggested the incorporation of sustainably managed methods in conjugation with the traditional customs and practices to maintain environmental boundary conditions (Dasgupta et al. 2021) The effective implementation of schemes, eco-development plans to promote agroforestry and tree-based land uses with the help of local tribes may reshape the adversities of shifting cultivation and intensive cultivation (NEPED 1999, Sati 2020).

CONCLUSION

Shifting cultivation in Nagaland supports a large portion (60%) of livelihood and food security,maintain peace and harmony among the indigenous tribal communities while it severely affects the environmental systems primarily the loss of green infrastructure. The study highlights the dominance of green infrastructure in the region, while has been altered due to shifting cultivation (9-17%) and fallow land (29.79% to 30.15%) over the last three decades. The topographical control was observed on hills with gentle slopes (>15%) with southeastern, south, and southwest aspects for shifting cultivation while an increase was observed in the higher relief. This will have a far more negative repercussion on the ecosystem. The reduction in the cycle of shifting cultivation and transformation to permanent intensive agricultural practices exacerbate the existing ecological condition. Thus, the study necessitates the incorporation of sustainably managed methods in conjugation with the traditional customs and practices to maintain environmental boundary conditions.

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