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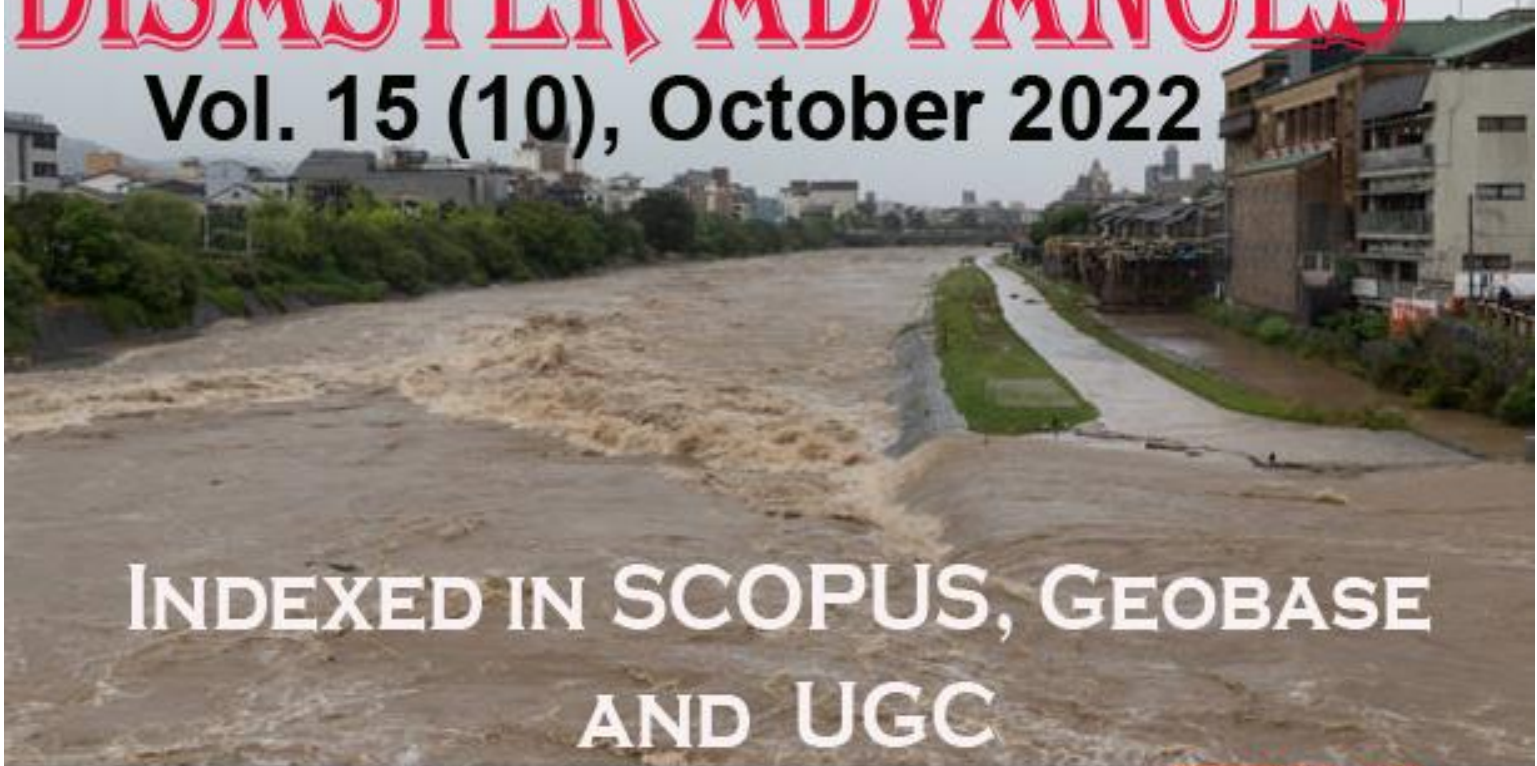
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Vulnerability level of forest degradation in Mizoram:
A spatio-temporal density analysis

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Abstract
With vast forest cover from the total geographical area, Mizoram had been experiencing forest degradation for more than a decade. The present study attempts to assess the rate of forest degradation in different districts of Mizoram. The vulnerability level of forest degradation is determined by statistical techniques. The result reveals that Saiha district falls in the very highly vulnerable zone of forest degradation followed by Champhai and Kolasib districts in highly vulnerable zones.

Lawngtlai district is in the moderately highly vulnerable zones and Aizawl and Lunglei districts are in the moderately vulnerable zone. Mamit district is in low vulnerable zones and Serchhip district has no vulnerability status of forest degradation.

Keywords: Vulnerability, Forest Degradation, Rate of deforestation, Composite Score.

Introduction

Among the States and Union Territories of India, Mizoram is highly incomparable with other States in the richness of its forest resources. It is endowed with a moderate climate and a good amount of rainfall has led to the speedy growth of vegetation which reduces the recycling period of the Jhum land. Moreover, it has a large coverage of forest from the total geographical area (TGA) and often stands among the highest rank at the national level as assessed by the Forest Survey of India. But in the recent decade, Mizoram has lost its forest quality as well as quantity. Negative changes have been experienced up to the last assessment of 2021 since 2009. This can be due to different factors of anthropogenic activities and natural calamities. Therefore, assessment of the forest degradation vulnerability level is a pre-requisite for combating forest degradation and for suggesting certain significant forest conservation measures.

State of Forest Report 2009- 2021[10] reveals that the total loss of forest cover in Mizoram is 1420.49 km^2 and has negative changes in every reporting year within the present decade. The largest forest cover loss found between the years 2015 and 2017 is 562 km^2. The latest State of Forest Report (2021)[10] shows that 186 km^2 of forest cover was decreased from the previous assessment in the year 2019 (Table 1).

Forest vulnerability assessment has been studied by researchers and experts at the national level[1,3,8] as well as regional level[2,4,7,9]. But those studies were related to climate change and species of trees and adopted different models and methods to determine the level of vulnerability in the forest. Unlike the previous studies, the present study aimed to assess the rate of forest degradation and to determine the vulnerability level of forest degradation from the existing data. The term vulnerability has been used by various research communities in many different ways.

In the present study, vulnerability implies susceptibility to change in the quality and the quantity of forest to the subordinate forest types. It is mainly caused by the consequences of anthropogenic activities and other factors like slash and burns agricultural practices, negligent forest fires and other developmental works. The main objectives of the studies are:

1. To find out the rate of forest degradation in eight districts of Mizoram and 2. To determine the vulnerability level of forest degradation.

Table 1
Total forest cover change in Mizoram

Year	Total Forest cover in km^2	Change in km^2
2005	18684	----
2009	19240	+556
2011	19117	-123
2013	19054	-63
2015	18748	-306
2017	18186	-562
2019	18005.51	-180.49
2021	178260	-186
Total		**-1420.49**

Study Area

The State of Mizoram is one of the eight sister States in the north-eastern region and is situated in the southernmost part between 21° 56' and 24° 31' N latitudes and 92° 16' and 92°26' E longitudes[5]. It is bound by the State of Assam on the north and the State of Manipur on the northeast and shares an international boundary on the east with Myanmar and on the west by the State of Tripura and shares an international boundary with Bangladesh (Fig.1). The total areal extent of the State is 21,081 km[2] and divided into eight districts. According to the State of Forest Report (2019), the total coverage of forests in Mizoram is 85.41 % from TGA which declined by about 91.27% in only ten years (2009). Among the districts, Mamit (89.81%) has the largest cover from TGA followed by Lunglei (88.67%), Aizawl (86.10%), Lawngtlai (86.04%), Saiha (84.74%), Kolasib (83.40%) and Serchhip (81.75%). The least forest cover of 78.11% is found in the Champhai district.

Material and Methods

The present study is entirely based on the analysis of secondary data generated by the State of Forest Report from 2005 to 2019. The study aims to evaluate the rate of forest degradation in the eight districts of Mizoram through the method of calculating the deforestation rate given by Puyravoud[6] using Microsoft excel and the annual rate of forest change is derived from the compound interest formula due to its explicit biological meaning.

Change rate = [Ln (At1)Ln (At0)] / t1 –t0 x 100

where the change rate is percentage per year, At1 is the area of class in the current year, At0 is the area of class in the base year, t1 is the current year, t0 is the base year and Ln is the natural logarithm.

The composite score was taken from the average value of different factors for determining the vulnerability and classified them into different levels of very highly vulnerable (VHV), highly vulnerable (HV), moderately high vulnerable (MHV), moderately vulnerable (MV), low vulnerable (LV) and not vulnerable (NV) by the technique of Jenks Natural Breaks under the environment of ArcGIS 10.5.

Results and Discussion

The total forest cover of Mizoram is showing a decreasing trend in recent years (2005-2019) at a rate of -0.28 percent per year. During the assessment period, the very dense forest (VDF) has an average of 1.39 percent per year which is the only forest type showing a positive change. Moderately dense forest (MDF) and open forest (OF) have average negative changes of -0.41 and -0.24 percent per year respectively (Table 2).
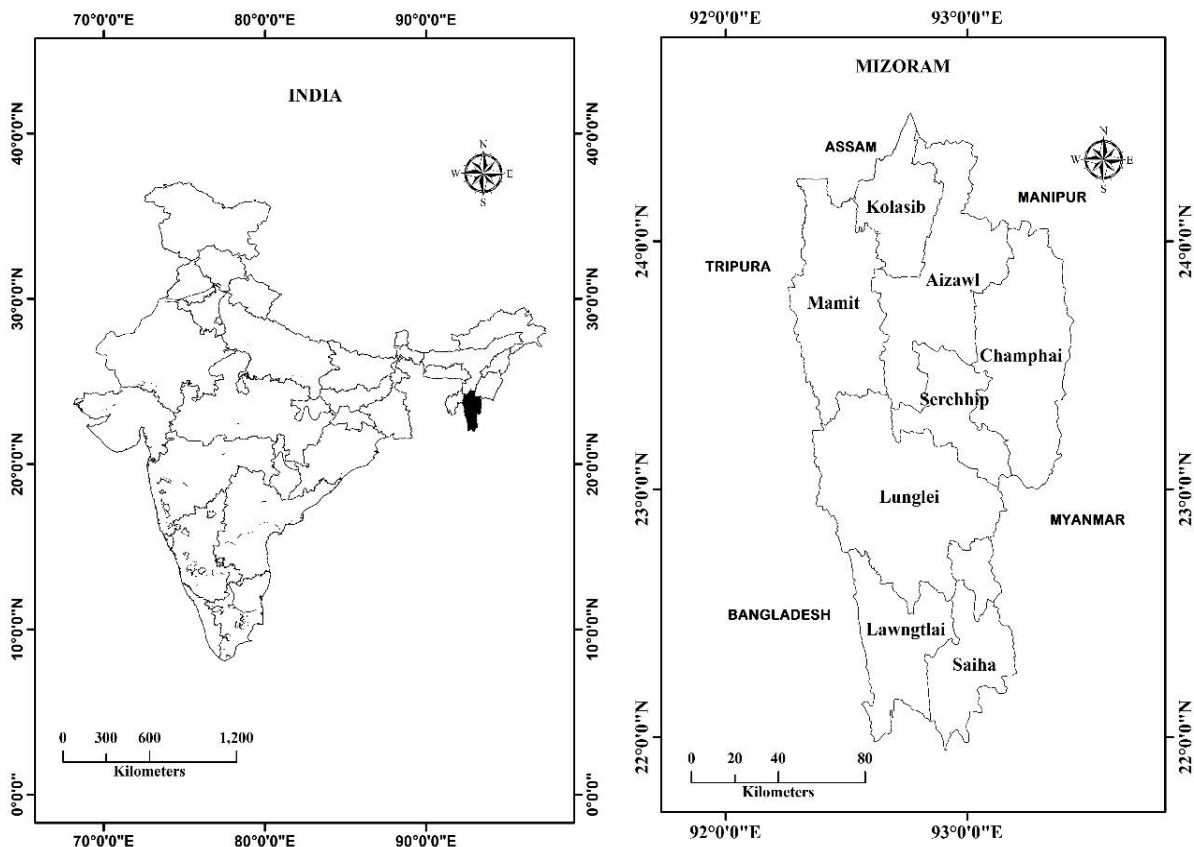

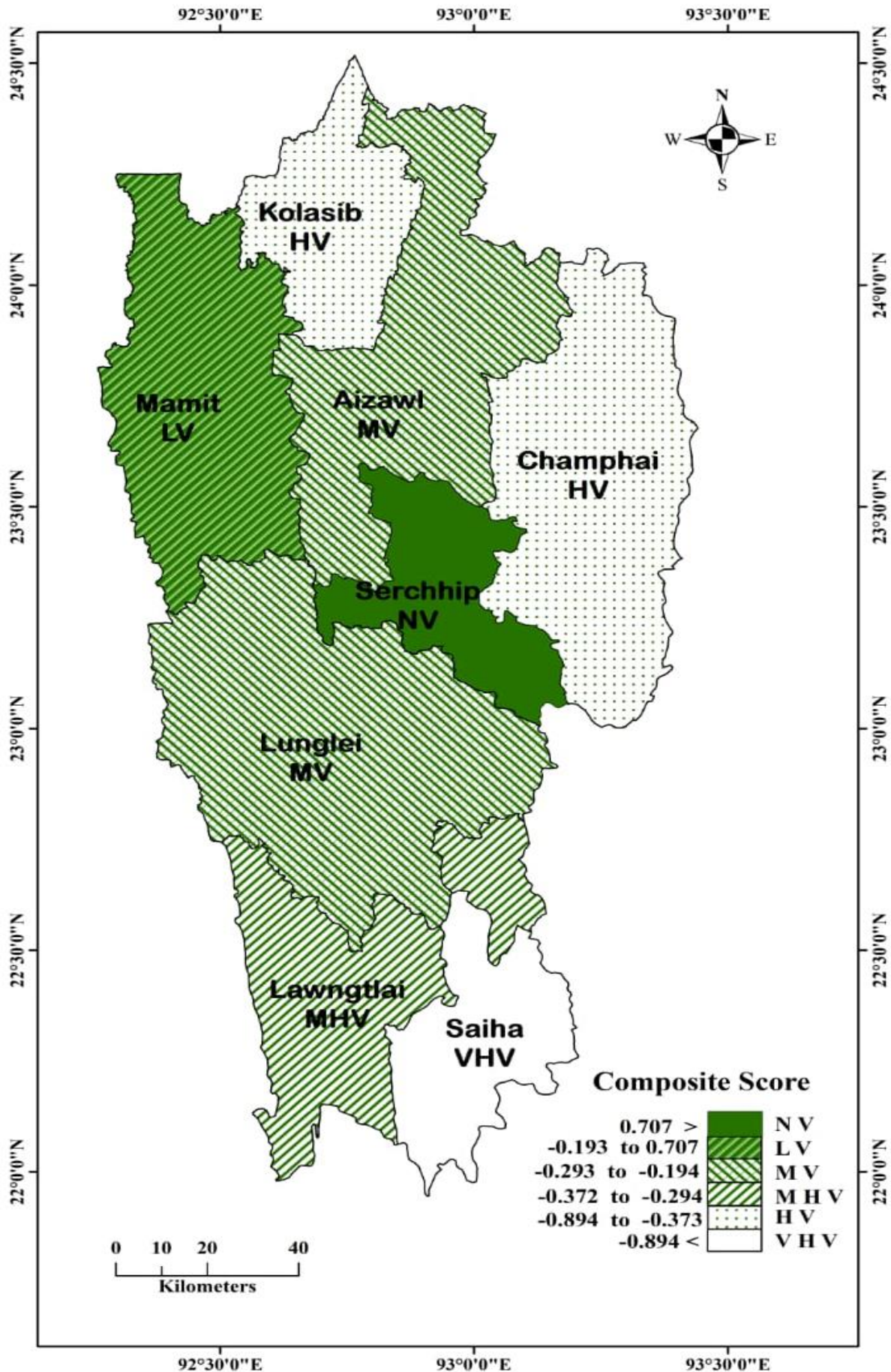**Fig. 1: Location map of the study area.**

Fig. 2: Vulnerability level of forest degradation in the districts of Mizoram.

Table 2
Details of the different types of forest in Mizoram with change rate in percent per year

District	Year	VDF Area in km²	% from TGA	Change in % per year	MDF Area in km²	% from TGA	Change in % per year	OF Area in km²	% from TGA	Change in % per year	Total Area in km²	% from TGA	Change in % per year
Aizawl	2005	34	0.95		1068	29.87		2055	57.47		3157	88.28	
	2009	32	0.89	-3.03	1013	28.33	-2.64	2278	63.70	5.15	3323	92.93	2.56
	2011	26	0.73	-5.19	1205	33.70	4.34	2034	56.88	-2.83	3265	91.30	-0.44
	2013	30	0.84	7.16	1168	32.66	-1.56	2051	57.35	0.42	3249	90.86	-0.25
	2015	28	0.78	-3.45	1135	31.74	-1.43	2022	56.54	-0.71	3185	89.07	-0.99
	2017	18	0.50	-22.09	1092	30.54	-1.93	1984	55.48	-0.95	3094	86.52	-1.45
	2019	30.3	0.85	26.04	1071.37	29.96	-0.95	1977.24	55.29	-0.17	3078.91	86.10	-0.24
	Average			**-0.09**			**-0.70**			**0.15**			**-0.14**
Champhai	2005	57	1.79		1248	39.18		1299	40.78		2604	81.76	
	2009	58	1.82	0.87	1180	37.05	-2.80	1519	47.69	7.82	2757	86.56	2.85
	2011	57	1.79	-0.43	1096	34.41	-1.85	1632	51.24	1.79	2785	87.44	0.25
	2013	60	1.88	2.56	1058	33.22	-1.76	1647	51.71	0.46	2765	86.81	-0.36
	2015	60	1.88	0.00	1042	32.72	-0.76	1570	49.29	-2.39	2672	83.89	-1.71
	2017	56	1.76	-3.45	1012	31.77	-1.46	1535	48.19	-1.13	2603	81.73	-1.31
	2019	55.62	1.75	-0.34	1003.68	31.51	-0.41	1428.49	44.85	-3.60	2487.79	78.11	-2.26
	Average			**-0.13**			**-1.51**			**0.49**			**-0.42**
Kolasib	2005	0	0.00		255	18.45		1011	73.15		1266	91.61	
	2009	0	0.00	0.00	210	15.20	-9.71	1090	78.87	3.76	1300	94.07	1.33
	2011	0	0.00	0.00	175	12.66	-4.56	1046	75.69	-1.03	1221	88.35	-1.57
	2013	0	0.00	0.00	191	13.82	4.37	1038	75.11	-0.38	1229	88.93	0.33
	2015	0	0.00	0.00	187	13.53	-1.06	1027	74.31	-0.53	1214	87.84	-0.61
	2017	0	0.00	0.00	172	12.45	-4.18	1010	73.08	-0.83	1182	85.53	-1.34
	2019	1.24	0.09	10.76	168.37	12.18	-1.07	982.94	71.12	-1.36	1152.55	83.40	-1.26
	Average			**1.79**			**-2.70**			**-0.06**			**-0.52**
Lawngtlai	2005	0	0.00		708	27.69		1623	63.47		2331	91.16	
	2009	0	0.00	0.00	699	27.34	-0.64	1681	65.74	1.76	2380	93.08	1.04
	2011	0	0.00	0.00	704	27.53	0.18	1664	65.08	-0.25	2368	92.61	-0.13
	2013	0	0.00	0.00	704	27.53	0.00	1646	64.37	-0.54	2350	91.90	-0.38
	2015	0	0.00	0.00	705	27.57	0.07	1632	63.82	-0.43	2337	91.40	-0.28
	2017	0	0.00	0.00	704	27.53	-0.07	1518	59.37	-3.62	2222	86.90	-2.52
	2019	0	0.00	0.00	703.59	27.52	-0.03	1496.49	58.53	-0.71	2200.08	86.04	-0.50
	Average			**0.00**			**-0.08**			**-0.63**			**-0.46**
Lunglei	2005	0	0.00		1291	28.46		2970	65.48		4261	93.94	
	2009	0	0.00	0.00	1586	34.96	10.29	2698	59.48	-4.80	4284	94.44	0.27
	2011	1	0.02	0.00	1233	27.18	-6.29	2972	65.52	2.42	4206	92.72	-0.46
	2013	1	0.02	0.00	1192	26.28	-1.69	3003	66.20	0.52	4196	92.50	-0.12
	2015	1	0.02	0.00	1186	26.15	-0.25	2954	65.12	-0.82	4141	91.29	-0.66
	2017	1	0.02	0.00	1195	26.34	0.38	2826	62.30	-2.21	4022	88.67	-1.46
	2019	0.99	0.02	-0.50	1190.13	26.24	-0.20	2831.05	62.41	0.09	4022.17	88.67	0.00
	Average			**-0.08**			**0.37**			**-0.80**			**-0.40**
Mamit	2005	39	1.29		628	20.76		1976	65.32		2643	87.37	
	2009	41	1.36	2.50	568	18.78	-5.02	2137	70.64	3.92	2746	90.78	1.91
	2011	45	1.49	2.33	697	23.04	5.12	2032	67.17	-1.26	2774	91.70	0.25
	2013	41	1.36	-4.65	644	21.29	-3.95	2091	69.12	1.43	2776	91.77	0.04
	2015	43	1.42	2.38	654	21.62	0.77	2044	67.57	-1.14	2741	90.61	-0.63
	2017	43	1.42	0.00	772	25.52	8.29	1885	62.31	-4.05	2700	89.26	-0.75
	2019	52.02	1.72	9.52	757.8	25.05	-0.93	1907.05	63.04	0.58	2716.87	89.81	0.31
	Average			**2.01**			**0.71**			**-0.09**			**0.19**
Saiha	2005	0	0.00		612	43.75		733	52.39		1345	96.14	
	2009	0	0.00	0.00	568	40.60	-3.73	723	51.68	-0.69	1291	92.28	-2.05
	2011	0	0.00	0.00	629	44.96	2.55	703	50.25	-0.70	1332	95.21	0.78

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District	Year	VDF area	VDF %	VDF change	MDF area	MDF %	MDF change	OF area	OF %	OF change	Total area	Total %	Total change
	2013	0	0.00	0.00	553	39.53	-6.44	712	50.89	0.64	1265	90.42	-2.58
	2015	0	0.00	0.00	551	39.39	-0.18	696	49.75	-1.14	1247	89.14	-0.72
	2017	0	0.00	0.00	548	39.17	-0.27	657	46.96	-2.88	1205	86.13	-1.71
	2019	0	0.00	0.00	545.11	38.96	-0.26	640.38	45.77	-1.28	1185.49	84.74	-0.82
	Average		**0.00**			**-1.39**			**-1.01**			**-1.18**
Serchhip	2005	3	0.21		363	25.55		711	50.04		1077	75.79	
	2009	3	0.21	0.00	366	25.76	0.41	749	52.71	2.60	1118	78.68	1.87
	2011	5	0.35	12.77	408	28.71	2.72	794	55.88	1.46	1207	84.94	1.91
	2013	6	0.42	9.12	390	27.45	-2.26	828	58.27	2.10	1224	86.14	0.70
	2015	6	0.42	0.00	398	28.01	1.02	807	56.79	-1.28	1211	85.22	-0.53
	2017	13	0.91	38.66	366	25.76	-4.19	779	54.82	-1.77	1158	81.49	-2.24
	2019	16.88	1.19	13.06	360.7	25.38	-0.73	784.07	55.18	0.32	1161.65	81.75	0.16
	Average		**12.27**			**-0.51**			**0.57**			**0.31**
Mizoram	2005	133	0.63		6173	29.28		12378	58.72		18684	88.63	
	2009	134	0.64	0.37	6251	29.65	0.63	12855	60.98	1.89	19240	91.27	1.47
	2011	134	0.64	0.00	6086	28.87	-0.67	12897	61.18	0.08	19117	90.68	-0.16
	2013	138	0.65	1.47	5900	27.99	-1.55	13016	61.74	0.46	19054	90.38	-0.17
	2015	138	0.65	0.00	5858	27.79	-0.36	12752	60.49	-1.02	18748	88.93	-0.81
	2017	131	0.62	-2.60	5861	27.80	0.03	12194	57.84	-2.24	18186	86.27	-1.52
	2019	157.05	0.74	9.07	5800.75	27.52	-0.52	12047.71	57.15	-0.60	18005.51	85.41	-0.50
	Average		**1.39**			**-0.41**			**-0.24**			**-0.28**

Table 3
Average rate of changes in different forest types

District	VDF	MDF	OF	Total	Composite Score
Aizawl	-0.09	-0.70	0.15	-0.14	-0.19
Champhai	-0.13	-1.51	0.49	-0.42	-0.39
Kolasib	1.79	-2.7	-0.06	-0.52	-0.37
Lawngtlai	0.00	-0.08	-0.63	-0.46	-0.29
Lunglei	-0.08	0.37	-0.80	-0.40	-0.23
Mamit	2.01	0.71	-0.09	0.19	0.71
Saiha	0.00	-1.39	-1.01	-1.18	-0.90
Serchhip	12.27	-0.51	0.57	0.31	3.16

The total coverage of VDF in Mizoram is increasing from 133 km² (0.63% from TGA) in 2005 to 157.05 km² (0.74% from TGA) by 2019 (Table 2). But negative change rate (-2.6 % per year) was found between the years 2015 and 2017 and filled the gap by the next assessment of 2017-2019 with a high rate of 9.07 % per year (Table 2).

Among the districts of Mizoram as per the recent data of the year 2019, Champhai district (1.75% or 55.62 km²) has the largest area of VDF cover from the total geographical area followed by Mamit district (1.72% of TGA or 52.02 km²), Serchhip district (1.19% of TGAor 16.88 km²), Aizawl district (0.85% of TGA or 30.3 km²), Kolasib district (0.09% of TGA or 1.24 km²) and Lunglei district (0.02% of TGA or 0.99 km²). The two southernmost districts of Lawngtlai and Saiha do not have measurable VDF cover for the entire assessment period.

Regarding the rate of change % per year within the assessment period, the Serchhip district has the highest average rate (12.27) followed by the Mamit district (2.01) and Kolasib district (1.79). They are the only three districts having a positive change rate in VDF type. Other districts like Lunglei (-0.08), Aizawl (-0.09) and Champhai (-0.13)

show negative average change rates. There is no average change rate in Lawngtlai district and Saiha district due to the absence of VDF type. The main causes of the negative changes and the absence of VDF are perhaps the demand for land for agriculture practices and other economic activities to satisfy the needs of the ever-increasing population.

Contrary to the VDF, the total coverage area of MDF cover in Mizoram has decreased from 6173 km² (29.28% of TGA) in 2005 to 5800.75 km² (27.52% of TGA) in 2019 losing 372.25 km². The average rate of change has a negative value (-0.41 % per year) but found a low rate of positive change in the year 2005-09 (0.63) and 2015-17 (0.03) (Table 3). Saiha district with 545.11 km² (38.96 %) has the largest area of MDF cover from the total geographical area in 2019 followed by Champhai district (31.51 % of TGA or 1003.68 km²), Aizawl district (29.96 % of TGA or 1071.37 km²), Lawngtlai district (27.52 % of TGA or 703.59 km²), Lunglei district (26.24 % of TGA or 1190.13 km²), Serchhip district (25.38 % of TGA or 360.7 km²), Mamit (25.05 % of TGA or 757.8 km²) and Kolasib districts (12.18 % of TGA or 168.37 km²). Among the eight districts of Mizoram, only two districts namely Mamit (0.71) and Lunglei (0.37) have an average rate of positive change % per year respectively.

Table 4
Vulnerability level of forest in different districts of Mizoram

District	Composite Score	Vulnerability Status
Saiha	< -0.894	Very High Vulnerable (VHV)
Champhai, Kolasib	-0.894 to -0.373	High Vulnerable (HV)
Lawngtlai	-0.372 to -0.294	Moderately High Vulnerable (MHV)
Aizawl, Lunglei	-0.293 to -0.194	Moderately Vulnerable (MV)
Mamit	-0.193 to 0.707	Low Vulnerable (LV)
Serchhip	> 0.707	No Vulnerable (NV)

Districts showing a negative change rate percent per year are Kolasib (-2.7) followed by Champhai (-1.51), Saiha (-1.39), Aizawl (-0.7), Serchhip (-0.51) and Lawngtlai (-0.08).

Similar to the MDF, the average rate of change in OF has a negative value of -0.24 % per year during the assessment period between 2005 and 2019. The total coverage area was found largest in 2013 (13,016 km^2) which increased from 2005 (12,375 km^2) and decreased to only 12,047.71 km^2 in 2019. The latest data published by the Forest Survey of India in the year 2019 show that the Kolasib district (71.12 % or 982.94 km^2) has the largest area of cover from the total geographical area (TGA).

It is followed by Mamit (63.04 % or 1907.05 km^2) and Lunglei districts (62.41 % or 2831.05 km^2). Other districts like Lawngtlai, Aizawl and Serchhip have 58.53 % or 1496.49 km^2, 55.29 % or 1977.24 km^2 and 55.18 % or 784.07 km^2 respectively.

The least two districts are Saiha (45.77 % or 640.38 km^2) and Champhai districts (44.85 % or 1428.49 km^2). The average forest change rate of % per year is highest in the Serchhip district with a positive value of 0.57. Two other districts are having positive changes viz. Champhai (0.49) and Aizawl (0.15). The remaining five districts show a negative average change rate as the highest change rate found in the Saiha district (-1.08) followed by Lunglei (-0.8), Lawngtlai (-0.63), Mamit (-0.09) and Kolasib (-0.06) respectively.

The average total change of forest in different districts of Mizoram during the assessment period reveals that only the two districts of Serchhip (0.31) and Mamit (0.19) have a positive average change rate of % per year. The other remaining six districts have a negative average change rate. The least negative average change rate was found in Saiha (-1.18) followed by Kolasib (-0.52). Other districts having negative average change rates are Aizawl (-0.14), Lunglei (-0.40), Champhai (-0.42) and Lawngtlai (-0.46). The composite score was analyzed from the different types of forest and total forest change average rate in % per year to determine the vulnerability level of forest resources in Mizoram.

Saiha district stands in a very highly vulnerable zone of forest degradation followed by Champhai district and Kolasib district in the highly vulnerable zones (Table 4).

Lawngtlai district is in the moderately highly vulnerable zone. Aizawl and Lunglei districts are in a moderate vulnerable zone. Mamit district has a positive average change rate in VDF, MDF and total forest cover and only a less negative change rate in OF, which made it fall in a lower vulnerability zone of forest degradation. Serchhip district has no vulnerability status of forest degradation and has a negative change rate only in MDF. The negative changes have led to expanding the area of VDF.

Conclusion
The present study reveals the wealth of Mizoram forest resources. The forest cover has been degrading in recent years with a moderate change in quality and quantity. In some districts, the best quality type of forest VDF has vanished and the coverage area of MDF and OF is also decreasing. These have been hazardous negative impacts on the growth and development of forests in Mizoram. Therefore, it is essential to develop forest resources with appropriate management strategies and compulsorily needed to adopt effective measures of a conservation plan for combating forest degradation in different districts of Mizoram based on their vulnerability levels to degradation.

The Government can adopt effective measures like afforestation and promoting community-based forest management successfully practiced in some villages. Replacing agricultural practices of shifting cultivation with permanent horticultural practices to check further forest degradation can become one of the most effective methods.

Acknowledgment

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