Assessment of Vulnerability of Arunachal Pradesh (India) to Floods

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Abstract

Arunachal Pradesh, due to its location near the two main river systems of the north-east India, namely, Brahmaputra and the Barak (Meghna), its unique location in the fragile geo-environmental setting of eastern Himalayan periphery and due to its poor adaptive capacity, is very much vulnerable to water induced disasters like flood. As such, vulnerability assessment of this state to flood is very important. In the present study, assessment of vulnerability of Arunachal Pradesh to floods had been carried out using Unequal Weights Index Method defined by Iyengar and Sudershan. Difference in units and types of association was resolved through converting indicators into normalized positive values that range from zero to one using UNDP's Human Development Index (HDI) based on the functional relationship between the indicators and vulnerability. The study reveals that vulnerability indices for hazard are more than 0.5 in 7 districts i.e. Papumpare, Changlang, Lower Dibang Valley, Upper Siang, West Siang, Upper Subansiri and East Kameng. Vulnerability indices for exposure are found to be more than 0.5 in 3 districts i.e., Lower Subansiri, Changlang and Tirap. The vulnerable districts in terms of adaptive capacity having vulnerability index more than 0.5 are 12 districts i.e Dibang valley, Anjaw, Upper Siang, Tirap, Tawang, Lower Dibang Valley, East Kameng, West Kameng, Kurung Kumey, Upper Subansiri, Lower Subansiri and Changlang. These shows that each district performs differently with respect to the different components of vulnerability. Composite vulnerability indices of 10 districts are more than 0.5 i.e., Upper Siang, Anjaw, Dibang Valley, Lower Dibang Valley, Changlang, Lower Subansiri, Tirap, East Kameng, Kurung Kumey and West Kameng which make them more vulnerable to flood in Arunachal Pradesh.

Introduction

The word 'vulnerability' is usually associated with natural hazards like flood, drought, and social hazards like poverty etc. The Intergovernmental Panel on Climate Change (IPCC), in its Second Assessment Report, defines vulnerability as "the extent to which climate change may damage or harm a system." Chamber (1983) defined that vulnerability has two sides. One is external side of risks, shocks to which an individual or household is subject to climate change and an internal side which is defenceless, meaning a lack of means to cope without damaging loss. Vulnerability is often reflected in the condition of the economic system as well as the socioeconomic characteristics of the population living in that system (Unmesh and Narayanan, 2009). Water resource systems are vulnerable to floods due to three main factors; hazard, exposure and adaptive capacity. Hazard is defined as a physical manifestation of climate change. Exposure can be understood as the values that are present at the location where floods can occur. Adaptive capacity is the ability of an entity – a country, a community, or an individual – to take action to cope better with current or potential adverse conditions brought about by hazards. Area that have high exposure and low coping capabilities would have the highest risk from a given drought event and those with low exposure and high coping abilities would have the lowest risk.

Many studies on quantitative assessment of vulnerability such as Luers et al. (2003), Moss et al. (2001), Kaly et al. (2002), Downing et al. (2001), Pritchett et al. (2000), and Schimmelpfennig and Yohe (1999) illustrated the composite index approach to measuring vulnerability. For instance, Moss et al. (2000) in the Pacific Northwest Laboratory (PNL) used an index which is a composite of 16 variables selected from five sensitive sectors (settlement, food security, human health, ecosystem, and water) and three dimensions for coping capacity (economic, human resources, and environmental) to measure vulnerability to climate change for 38 countries.

India being the worst flood affected country next to Bangladesh accounts one fifth of the global deaths by flood every year and on an average 30 million people are evacuated every year. The area vulnerable to flood is 40 million hectare and average area affected by flood is 8 million hectare. The North East region of India, consisting of eight states covering a geographic area of 26.2 mha and a population of 40 million, is characterized by large rural population (82%), low population density, large percentage of indigenous tribal communities (34–91%) and large area under forests (60%). The region has two main river basin (the Brahmaputra and Barak), a large dependence of the population on natural resources, and poor infrastructure development. The region is also characterized by diverse climate regimes which are highly dependent on the southwest monsoon (June–September). Over 60% of the crop area is under rainfed agriculture, and so is in areas highly vulnerable to climate variability and climate change (Ravindranath et al., 2011). Arunachal Pradesh, due to its location near the two river systems mentioned above, its unique location in the fragile geo-environmental of eastern Himalayan periphery and due to poor adaptive capacity, is very much vulnerable to water induced disasters like flood. Considering the importance of vulnerability assessment of Arunachal Pradesh to floods, present study was undertaken with following objectives:

- To assign weights to indicators for hazard, exposure, and adaptive capacity for estimation of vulnerability indices for floods.
- To determine vulnerable districts for floods in Arunachal Pradesh.

Materials and Methods

Description of study area

Arunachal Pradesh is situated between 26º 30' and 29º 28' N latitudes and 91º 25' to 97º 24' E longitudes. It covers an area of 83,700 sq. km. The state is bounded by China and Tibet in the north, Assam in the south, in the east by Myanmar and Nagaland, and in the west by Bhutan. The area of Arunachal Pradesh can be broadly divided into four distinct Physiographic regions:

1. The greater Himalayas with snow clapped mountains with altitudes rising up to 5,500 m above mean sea level
2. The lower Himalayas range up to 3,500 m altitude
3. The sub-Himalayas belt including the Siwalik hills, altitude up to 1,700 m above mean sea level
4. The plains which are the eastern constitute of Assam plains. The elevation of plains varies from 80 to 210 m above mean sea level and it is drained by different rivers.

The study area is presented in Fig.1. The climate of Arunachal Pradesh is humid to per humid subtropical characterized by high rainfall and high humidity and sub-Himalayan belt. However, temperate climate prevails at lower Himalayan region. The greater Himalayan region is covered with perpetual snow. The latitude, longitude and elevation values for all the 16 districts are shown in Table 1. The average annual rainfall varies from 1,380 to 5,500 mm.

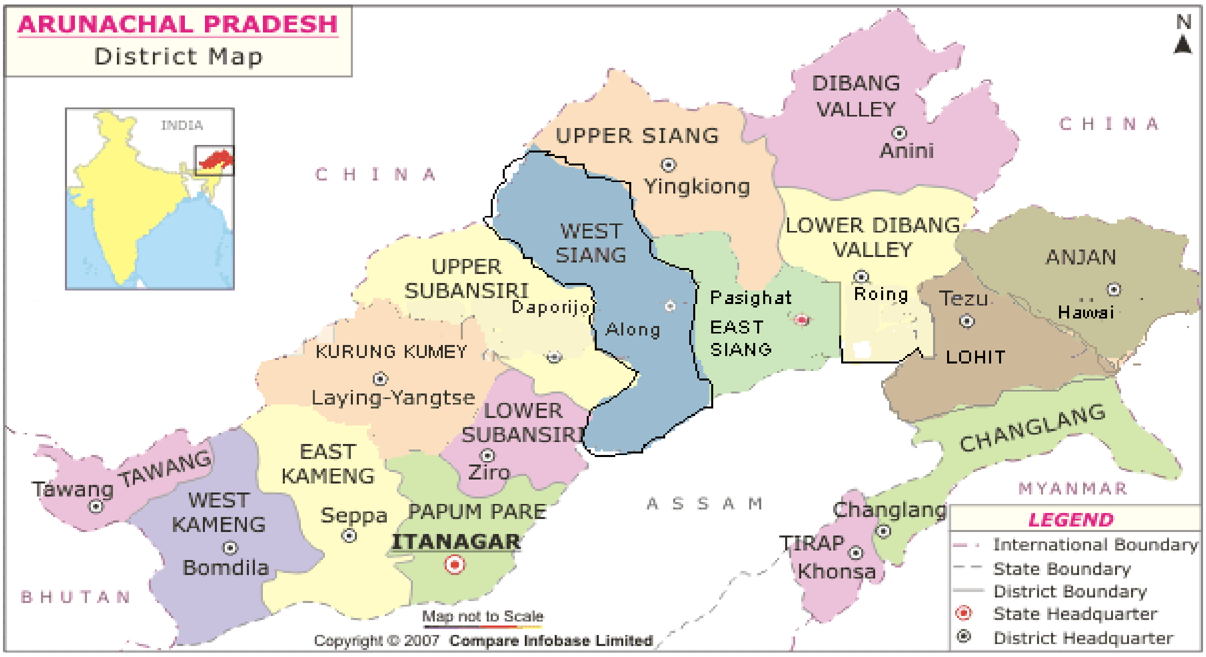

Fig. 1 Study Area (16 Districts of Arunachal Pradesh)

Table 1 Different districts of Arunachal Pradesh

Sl. No	District	HQ	Latitude, °N	Longitude, °E	Altitude, m
1	Anjaw	Hawai	27.88	96.81	1296
2	Changlang	Changlang	27.12	95.71	580
3	East Kameng	Seppa	27.32	93.00	363
4	East Siang	Pasighat	28.07	95.34	155
5	KurungKumey	Koloriang	27.87	93.35	2300
6	Lohit	Teju	27.92	96.17	244
7	Lower Dibang Valley	Roing	28.14	95.83	1800
8	Lower Subansiri	Ziro	27.56	93.80	1688
9	Papum Pare	Yupia (Itanagar)	27.07	93.59	440
10	Tawang	Tawang	27.59	91.87	2669
11	Tirap	Khonsa	27.19	95.47	1215
12	Upper Dibang Valley	Anini	28.79	95.89	1698
13	Upper Siang	Yingkiong	28.64	95.02	2500
14	Upper Subansiri	Daporijo	27.99	94.22	600
15	West Kameng	Bomdila	27.26	92.42	2217
16	West Siang	Along	27.98	94.70	619

Data acquisition

Values of different indicators of hazard, exposure and adaptive capacity were collected for 16 districts of Arunachal Pradesh from Directorate of Economics and Statistics Government of Arunachal Pradesh, Itanagar for 2010. The rainfall data for the period of 5 years (2005-2009) were collected from the Water Resource Department, Arunachal Pradesh and the average of this 5 years rainfall data were used for the analysis. The functional relationship between indicators and vulnerability of the districts are shown in Table 2.

Table 2 Functional relationship between the indicators and vulnerability

Component	Sl.No.	Indicator	Functional Relationship
Hazard	1	Rainfall (H1)	↑
	2	Elevation (H2)	↓
Exposure	1	Density of population (E1)	↑
	2	Percentage of agricultural land to total (E2)	↑
	3	Percentage of rain fed land (E3)	↑
	4	Percentage of workforce in agriculture (E4)	↑
	5	Percentage of population on BPL(E5)	↑
	6	Percentage of rural population (E6)	↑
Adaptive Capacity	1	Land Area in sq.km (A1)	↓
	2	Electric power consumption (A2)	↓
	3	Total population (A3)	↓
	4	Decadal growth rate (A4)	↓
	5	Female percentage of total population (A5)	↓
	6	Literacy rate (A6)	↓
	7	Cereal yield in qntls per ha (A7)	↓
	8	Percentage of urban population (A8)	↓
	9	Primary stage education (A9)	↓
	10	Secondary stage education (A10)	↓
	11	Tertiary stage education (A11)	↓

Construction of vulnerability index

Construction of vulnerability index consists of several steps. First is the selection of study area which consists of several regions. In each region a set of indicators are selected for each of the three component of vulnerability. The indicators can be selected based the availability of data, personal judgement and previous research. Since vulnerability is dynamic over time, it is important that all the indicators related to the particular year should be chosen. If vulnerability has to be assessed over years then the data for each year for all the indicators in each region must be collected.

Arrangement of data

For each component of vulnerability, the collected data are arranged in the form of a rectangular matrix with rows representing regions and columns representing indicators. For M number of regions/districts and K number of indicators, X_{ij} will be the value of the indicator j corresponding to region i. Then the matrix table will have M rows and K columns.

Normalization of indicators using functional relationship

The methodology used in UNDP's Human Development Index (HDI) (UNDP, 2006) is followed to normalize indicators. Different indicators have different units. In order to obtain standardized values of indicators without any units, first they are normalized so that they all lie between 0 and 1. Before doing this, it is important to identify the functional relationship between the indicators and vulnerability. Two types of functional relationship are possible: vulnerability increases with increase in the value of the indicator or vulnerability increases with decrease in the value of the indicators. If the variables have increasing functional relationship with the vulnerability then normalization is done using the following formula:

$$X_{ij} = \frac{X_{ij} - Min\,\{X_{ij}\}}{Max\{X_{ij}\} - Min\,\{X_{ij}\}} \qquad (1)$$

And if the variables have decreasing functional relationship with the vulnerability then normalization is done using the formula as below:

$$Y_{ij} = \frac{Max\,\{X_{ij}\} - X_{ij}}{Max\{\,X_{ij}\} - Min\,\{X_{ij}\}} \qquad (2)$$

It is clear that all these scores will lie between 0 and 1. The value 1 will correspond to that region with maximum vulnerability and 0 will correspond to the region with minimum vulnerability. The method of normalization that takes into account the functional relationship between the variable and vulnerability is important in the construction of the indices. If the functional relation is ignored and the variables are normalized simply by applying Eqn. 1, the resulting index can be misleading. The normalised values of indicators are shown in Table 3, 4 and 5.

Iyengar and Sudershan's method (unequal weight method)

The method of simple averages gives equal importance for all the indicators which are not necessarily correct. Hence many authors prefer to give weights to the indicators. Iyengar and Sudarshan (1982) developed a method to work-out a composite index from multivariate data and it was used to rank the districts in terms of their economic performance. This methodology is statistically sound and well suited for the development of composite index of vulnerability to climate change also. A brief discussion of the methodology is given below. It is assumed that there are *M* regions/districts, K indicators of vulnerability and Xij (i = 1,2…M; j = 1,2,...K) is the normalized score. The level or stage of development of i^{th} zone, $\overline{Y}_i$, is assumed to be a linear sum of Xij as:

$$\overline{Y}_i = \sum_{j=1}^{K} w_j\, x_{ij} \qquad (3)$$

Where, w ($0 < w < 1$ and $\sum_{j=1}^{K} w_j = 1$) is the weight. In Iyengar and Sudarshan's method, the weights are assumed to vary inversely with the variance over the regions in the respective indicators of vulnerability. The weight w_j can be determined as:

$$w_j = {}^{c}\!/\!\sqrt{Var(x_{ij})} \qquad (4)$$

Where c is a normalizing constant and can be obtained as below:

$$c = \left[\sum_{j=1}^{j=k} \frac{1}{\sqrt{var(x_{ij})}}\right]^{-1} \qquad (5)$$

The determination of the weights in this manner would ensure that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter regional comparisons. The vulnerability index so computed lies between 0 and 1, with 1 indicating maximum vulnerability and 0 indicating no vulnerability at all.

Table 3 Normalized value of indicators for hazard

Sl. No.	District	Elevation of HQ	Maximum Rainfall for a given duration
1	Tawang	0.00	0.23
2	West Kameng	0.18	0.24
3	East Kameng	0.92	0.25
4	Papumpare	0.89	0.51
5	Lower Subansiri	0.39	0.06
6	Kurung Kumeng	0.15	0.33
7	Upper Subansiri	0.82	0.32
8	West Siang	0.82	0.40
9	East Siang	1.00	0.00
10	Upper Siang	0.07	1.00
11	Dibang Valley	0.39	0.33
12	Lower Dibang Valley	0.35	0.67
13	Lohit	0.96	0.14
14	Anjaw	0.55	0.12
15	Changlang	0.83	0.53
16	Tirap	0.58	0.17

Table 4 Normalised value of indicators for Exposure

Sl. No	District	Density of population	% of Agricultural land to total	% of rain fed land	% of workforce in agriculture	% of population BPL	% of rural population
1.	Tawang	0.41	0.16	0.27	0.02	0.07	0.55
2.	West Kameng	0.23	0.05	0.07	0.13	0.25	0.79
3.	East Kameng	0.32	0.20	0.26	0.06	0.38	0.46
4.	Papumpare	1.00	0.36	0.36	0.07	0.65	0.00
5.	Lower Subansiri	1.00	1.00	1.00	0.13	0.35	0.54
6.	KurungKumey	0.10	0.17	0.23	0.13	1.00	0.96
7.	Upper Subansiri	0.17	0.09	0.12	0.00	0.27	0.42
8.	West Siang	0.31	0.20	0.22	0.08	0.46	0.58
9.	East Siang	0.44	0.45	0.43	0.20	0.38	0.49
10.	Upper Siang	0.12	0.04	0.03	0.08	0.68	0.96
11.	Dibang Valley	0.01	0.00	0.00	0.64	0.10	0.96
12.	Lower Dibang Valley	0.30	0.28	0.38	0.64	0.28	0.58
13.	Lohit	0.26	0.13	0.18	0.68	0.00	0.56
14.	Anjaw	0.04	0.05	0.08	0.68	0.00	1.00
15.	Changlang	0.63	0.46	0.59	1	0.33	0.77
16.	Tirap	1.00	0.45	0.73	0	0.31	0.67

Table 5 Normalized value of indicators for Adaptive Capacity

Sl. No	Districts	Land area in sq. km	Electrical Power Consumption (kwh per capita)	Population	Decadal growth rate(2001-2011)	Female % of total population	Literacy rate	Cereal yield in Qntl per Ha	% of Urban population	Primary stage	Secondary education	Tertiary education
1.	Tawang	0.93	0.92	0.73	0.79	0.70	0.50	0.55	0.58	0.88	0.00	0.86
2.	West Kameng	0.48	0.79	0.43	0.90	0.79	0.19	0.64	0.82	0.70	0.77	0.66
3.	East Kameng	0.76	0.98	0.58	0.70	0.08	0.66	0.73	0.48	0.70	0.84	0.76
4.	Papum pare	0.87	0.00	0.03	0.92	0.32	0.00	0.00	0.00	0.00	0.51	0.00
5.	Lower Subansiri	1.00	0.92	0.59	0.59	0.14	0.23	0.46	0.56	0.55	0.79	0.56
6.	KurungKumey	0.36	0.99	0.70	0.00	0.00	1.00	0.78	0.56	0.57	0.96	0.92
7.	UppperSubansiri	0.51	0.96	0.59	0.58	0.14	0.44	0.50	0.44	0.38	0.78	0.49
8.	West Siang	0.46	0.93	0.18	0.98	0.28	0.22	0.75	0.60	0.29	0.48	0.11
9.	East Siang	0.71	0.95	0.32	0.93	0.23	0.20	0.20	0.51	0.54	0.57	0.16
10	Upper Siang	0.53	0.97	0.73	1.00	0.48	0.28	0.57	1.00	0.84	0.92	0.85
11	Dibang Valley	0.00	0.97	0.94	0.97	1.00	0.24	0.87	1.00	1.00	1.00	1.00
12	Lower Dibang Valley	0.70	0.97	0.60	0.99	0.45	0.14	0.76	0.61	0.80	0.83	0.64
13	Lohit	0.12	0.88	0.00	0.90	0.43	0.15	0.34	0.58	0.41	0.60	0.23
14	Anjaw	0.12	0.99	0.85	0.92	0.59	0.45	0.88	1.00	0.94	0.99	0.99
15	Changlang	0.64	0.88	0.00	0.88	0.30	0.26	0.04	0.81	0.50	0.72	0.46
16	Tirap	0.82	0.92	0.20	0.94	0.29	0.40	1.00	0.70	0.49	0.72	0.70

Results and Discussion

Construction of vulnerability index

Weights corresponding to the selected indicators of hazard, exposure and adaptive capacity were assigned using the unequal weight method defined by Iyengar and Sudershan and the vulnerability indices were calculated. The different components of vulnerability (hazard, exposure and adaptive capacity) were analyzed separately and same ranking approach was also used to assess vulnerability of the districts corresponding to hazard, exposure and adaptive capacity. For different components of vulnerability being considered, a district ranked differently. But overall ranking of a district considering composite vulnerability index was also determined to identify the hotspot or more vulnerable districts of Arunachal Pradesh to flood.

Vulnerability indices for hazard, exposure and adaptive capacity

Using Eqn. 4 for the values of the normalized hazard indicators given in Table 3, weights for hazard indicators were calculated. The resulting assigned weights are shown in Table 6. Further, using these weights and the normalised indicators in Eqn. 3, vulnerability indices and ranks of hazard for 16 districts were calculated. The vulnerability indices and ranks for hazard are shown in Table.7. The vulnerable districts in terms of hazard having vulnerability index more than 0.5 are Papumpare, Changlang, Lower Dibang valley, Upper Siang, West Siang, Upper Subansiri and East Kameng.

Similarly, the assigned weights and vulnerability indices for exposure and adaptive capacity were also calculated. The assigned weights and the indices with ranks for exposure district are given in Table 8 and Table 9 respectively. The vulnerable districts in terms of exposure having vulnerability index more than 0.5 are Lower Subansiri, Changalng and Tirap. The assigned weights and indices with ranks for adaptive capacity are shown in Table 10 and Table 11 respectively. The vulnerable districts in terms of adaptive capacity having vulnerability index more than 0.5 are Dibang valley, Anjaw, Upper Siang, Tirap, Tawang, West Kameng, East Kameng, Lower Subansiri, Kurung Kumey, Upper Subansiri, Lower Dibang Valley and Changlang.

Composite vulnerability index

For calculating the composite vulnerability index, the collected normalized indicators of hazard, exposure and adaptive capacity are arranged together in the form of rectangular matrix with rows representing regions and columns representing indicators as shown in Table 12. Then, using Eqn. 4, weights for each indicator were calculated. Calculated weights are shown in Table 13. Vulnerability indices for each district were calculated by using Eqn. 3 for normalized indicators from Table 12. Table 14 shows the composite vulnerability indices and ranks for the 16 districts of Arunachal Pradesh.

Table 6 Weights for hazard indicators

	Elevation at HQ (H1)	Rainfall (H2)	Total
Weight (w)	0.42	0.58	1

Table 7 Ranking of 16 districts based on vulnerability for hazard

District	VI	RANK
Tawang	0.14	16
West Kameng	0.21	14
East Kameng	0.53	5
Papumpare	0.67	1
Lower Subansiri	0.20	15
Kurung Kumeng	0.25	13
Upper Subansiri	0.53	5
West Siang	0.57	4
East Siang	0.42	9
Upper Siang	0.61	3
Dibang Valley	0.35	10
Lower Dibang Valley	0.53	5
Lohit	0.49	8
Anjaw	0.30	12
Changlang	0.66	2
Tirap	0.35	11

Table 8 Weights for exposure indicators

	Density of population (calculated) (E1)	% of agricultural land to total land (E2)	% of rain fed land (E3)	% of workforce in agriculture(E4)	Percentage of population BPL (E5)	% of rural population (E6)	Total
Weight(w)	0.14	0.19	0.17	0.14	0.18	0.18	1

Table 9 Ranking of 16 districts based on vulnerability for exposure

District	VI	RANK
Tawang	0.25	14
West Kameng	0.26	13
East Kameng	0.29	10
Papumpare	0.39	7
Lower Subansiri	0.68	1
Kurung Kumey	0.45	4
Upper Subansiri	0.19	16
West Siang	0.32	8
East Siang	0.40	6
Upper Siang	0.21	15
Dibang Valley	0.28	12
Lower Dibang Valley	0.41	5
Lohit	0.29	10
Anjaw	0.31	9
Changlang	0.62	2
Tirap	0.52	3

Table 10 Weights for adaptive capacity indicators

	Land Area in Sq.Km. (A1)	Eletrical Power Consumption (kwh Per capita) (A2)	Population (A3)	Percentage of decadal growth rate (2001-2011) (A4)	Female percentage of total population (A5)	Literacy rate (A6)	Cereal yield in qntls per ha (A7)	Percentage of Urban Populaiton (A8)	Total primary (A9)	Secondary education (A10)	Tertiary (A11)	Total
Weight(w)	0.08	0.10	0.08	0.10	0.09	0.10	0.08	0.10	0.09	0.10	0.08	1

Table 11 Ranking of 16 districts based on vulnerability for inadequate adaptive capacity

District	VI	RANK
Tawang	0.67	5
West Kameng	0.66	6
East Kameng	0.66	6
Papumpare	0.24	16
Lower Subansiri	0.58	10
Kurung Kumey	0.62	9
Upper Subansiri	0.53	12
West Siang	0.50	13
East Siang	0.50	13
Upper Siang	0.77	3
Dibang Valley	0.84	1
Lower Dibang Valley	0.66	6
Lohit	0.46	15
Anjaw	0.83	2
Changlang	0.54	11
Tirap	0.69	4

Table 12 The normalized arranged data for composite vulnerability index calculation

District	H1	H2	E1	E2	E3	E4	E5	E6	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Tawang	0.00	0.23	0.41	0.16	0.27	0.02	0.07	0.55	0.93	0.92	0.73	0.79	0.58	0.88	0.55	0.58	0.88	0.00	0.86
West Kameng	0.18	0.24	0.23	0.05	0.07	0.13	0.25	0.79	0.48	0.79	0.43	0.90	0.82	0.70	0.64	0.82	0.70	0.77	0.66
East Kameng	0.92	0.25	0.32	0.20	0.26	0.06	0.38	0.46	0.76	0.98	0.58	0.70	0.48	0.70	0.73	0.48	0.70	0.84	0.76
Papumpare	0.89	0.51	1.00	0.36	0.36	0.07	0.65	0.00	0.87	0.00	0.03	0.92	0.00	0.00	0.00	0.00	0.00	0.51	0.00
Lower Subansiri	0.39	0.06	1.00	1.00	1.00	0.13	0.35	0.54	1.00	0.92	0.59	0.59	0.56	0.55	0.46	0.56	0.55	0.79	0.56
Kurung Kumeng	0.15	0.33	0.10	0.17	0.23	0.13	1.00	0.96	0.36	0.99	0.70	0.00	0.56	0.57	0.78	0.56	0.57	0.96	0.92
Upper Subansiri	0.82	0.32	0.17	0.09	0.12	0.00	0.27	0.42	0.51	0.96	0.59	0.58	0.44	0.38	0.50	0.44	0.38	0.78	0.49
West Siang	0.82	0.40	0.31	0.20	0.22	0.08	0.46	0.58	0.46	0.93	0.18	0.98	0.60	0.29	0.75	0.60	0.29	0.48	0.11
East Siang	1.00	0.00	0.43	0.45	0.43	0.20	0.38	0.49	0.71	0.95	0.32	0.93	0.51	0.54	0.20	0.51	0.54	0.57	0.16
Upper Siang	0.07	1.00	0.12	0.04	0.03	0.08	0.68	0.96	0.58	0.97	0.78	1.00	1.00	0.84	0.57	1.00	0.84	0.92	0.85
Dibang Valley	0.39	0.33	0.00	0.00	0.00	0.64	0.10	0.96	0.00	0.97	1.00	0.97	1.00	1.00	0.87	1.00	1.00	1.00	1.00
Lower Dibang Valley	0.35	0.67	0.30	0.28	0.38	0.64	0.28	0.58	0.78	0.97	0.63	0.99	0.61	0.80	0.76	0.61	0.80	0.83	0.64
Lohit	0.96	0.14	0.25	0.13	0.18	0.68	0.00	0.56	0.14	0.89	0.00	0.90	0.58	0.41	0.34	0.58	0.41	0.60	0.23
Anjaw	0.55	0.12	0.03	0.05	0.08	0.68	0.00	1.00	0.14	1.00	0.91	0.92	1.00	0.94	0.88	1.00	0.94	0.99	0.99
Changlang	0.83	0.53	0.63	0.46	0.59	1.00	0.33	0.77	0.71	0.89	0.00	0.88	0.81	0.50	0.04	0.81	0.50	0.72	0.46
Tirap	0.58	0.17	1.00	0.45	0.73	0.00	0.31	0.67	0.91	0.93	0.21	0.94	0.70	0.49	1.00	0.70	0.49	0.72	0.70

Table 13 Weights for composite indicators

Component	Hazard		Exposure						Adaptive Capacity										
	H1	H2	E1	E2	E3	E4	E5	E6	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Standard Deviation(SD)	0.34	0.25	0.34	0.25	0.27	0.32	0.26	0.26	0.31	0.24	0.32	0.25	0.25	0.26	0.30	0.25	0.26	0.25	0.32
1/SD	2.91	3.97	2.95	3.99	3.67	3.08	3.79	3.83	3.27	4.17	3.10	3.94	3.94	3.79	3.37	3.94	3.79	3.99	3.11
c	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Weight	0.0424	0.0579	0.0430	0.0581	0.0535	0.0450	0.0552	0.0559	0.0477	0.0608	0.0452	0.0574	0.0574	0.0553	0.0491	0.0574	0.0553	0.0582	0.0454
Total weight																			1

Table 14 Composite Vulnerability indices and ranks for 16 districts

District	VI	RANK
Tawang	0.50	11
West Kameng	0.52	10
East Kameng	0.56	8
Papumpare	0.31	16
Lower Subansiri	0.61	5
Kurung Kumey	0.54	9
Upper Subansiri	0.44	14
West Siang	0.47	13
East Siang	0.50	11
Upper Siang	0.67	1
Dibang Valley	0.65	2
Lower Dibang Valley	0.63	4
Lohit	0.43	15
Anjaw	0.65	3
Changlang	0.61	6
Tirap	0.58	7

The vulnerable districts in terms of composite vulnerability having vulnerability index more than 0.5 are Upper Siang, Anjaw, Dibang valley, Lower Dibang valley, Changalng, Lower Subansiri, Tirap, East Kameng, Kurung kumey and West Kameng. Map indicating composite vulnerability of 16 districts is shown in Fig. 2. From the map it can be seen that there are 6 districts whose index values lie between 0.8 and 0.6 (Upper Siang, Anjaw, Dibang valley, Lower Dibang Valley, Changlang and Lower Subansiri). There are 9 districts with index values between 0.6 to 0.4 (Tirap, East Kameng, Kurung Kumey, West Kameng, East Kameng, Tawang, West Siang, Upper Subansiri and Lohit). Papumpare is the only district with vulnerability index in between 0.4 and 0.2.

Table 15 presents the top 5 most vulnerable districts or hotspots under hazard, exposure, adaptive capacity and composite vulnerability with vulnerability index more than 0.5.

Summary and Conclusion

Floods are part of the natural hydrological cycle, but adverse impacts arise when water masses inundate infrastructures and land that cannot cope with the excessive water. In the riverine environment, floods often have mixed impacts. They may produce benefits to some parts of the ecosystem and damages to other parts. Regular annual floods provide water resources for human use and carry nutrients supporting agricultural production on flood plains. Adverse impacts depend on the vulnerabilities of the area in question. The word ‘vulnerability’ is usually associated with natural hazards like flood, drought, and social hazards like poverty etc. The Intergovernmental Panel on Climate Change (IPCC), in its Second Assessment Report, defines vulnerability as “the extent to which climate change may damage or harm a system.” Hazard is defined as a physical manifestation of climate change. Exposure can be understood as the values that are present at the location where floods can occur. Adaptive capacity is the ability of an entity – a country, a community, or an individual

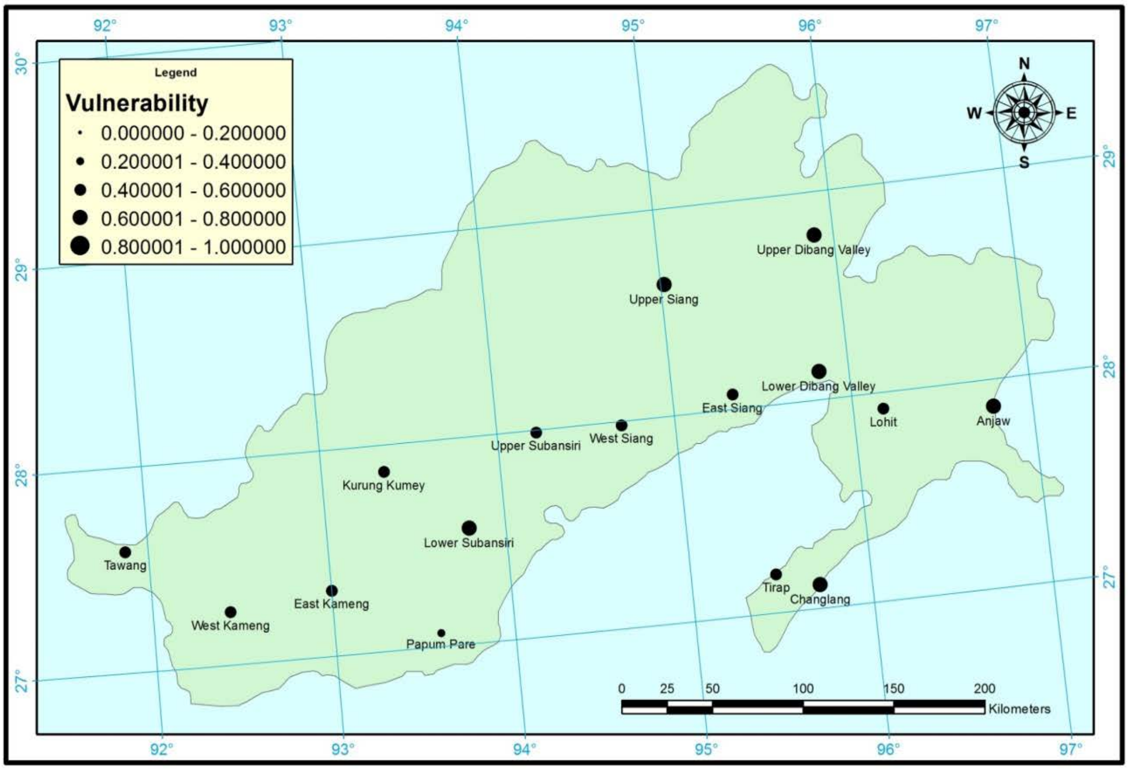

Fig. 2 Map indicating composite vulnerability of 16 districts

Table 15 Top five ranked most vulnerable districts or hotspots

Rank	**Hazard**	**Exposure**	**Adaptive Capacity**	**Composite Vulnerability Index**
1	Papumpare	Lower Subansiri	Dibang Valley	Upper Siang
2	Changlang	Chanaglang	Anjaw	Anjaw and Dibang valley
3	Upper Siang	Tirap	Upper Siang	Lower Dibang Valley
4	West Siang		Tirap	Lower Subansiri
5	Upper Subansiri, Lower Dibang Valley and East Kameng		Tawang	Changlang

– to take action to cope better with current or potential adverse conditions brought about by hazards.

The vulnerability of the north-east India to water induced disasters is of vital importance because of its poor adaptive capacity. Developing, testing and implementing indicators to identify and assess vulnerability to floods are an important pre-requisite for effective disaster risk reduction. Arunachal Pradesh, due to its location near these two river systems, its unique location in the fragile geo-environmental of eastern Himalayan periphery and due to poor adaptive capacity, is very much vulnerable to water induced disasters like flood. As such, vulnerability assessment of this state to flood is very important.

In the present study, assessment of vulnerability of Arunachal Pradesh to floods had been carried out using Unequal Weights defined by Iyengar and Sudershan. Values of selected indicators for hazard, exposure and adaptive capacity were collected for 16 districts of Arunachal Pradesh from Directorate of Economics and Statistics Government of Arunachal Pradesh, Itanagar. Difference in units and types of association was resolved through converting indicators into normalized positive values that range from zero to one using UNDP's Human Development Index (HDI) (UNDP, 2006) based on the functional relationship between the indicators and vulnerability.

The study was concluded with the following results:

1. Vulnerability indices for hazard are more than 0.5 for 7 districts i.e., Papumpare, Changlang, Lower Dibang Valley, Upper Siang, West Siang, Upper Subansiri and East kameng.
2. Vulnerability indices for exposure are more than 0.5 for 3 districts i.e., Lower Subansiri, Changlang and Tirap.
3. Vulnerability indices for inadequate adaptive capacity are more than 0.5 for 12 districts i.e Dibang valley, Anjaw, Upper Siang, Tirap, Tawang, Lower Dibang Valley, East kameng, West Kameng, Kuurng Kumey, Upper Subansiri, Lower Subansiri and Changlang.
4. For the composite vulnerability index, values of 10 districts are more than 0.5 i.e., Upper Siang, Anjaw, Dibang valley , Lower Dibang valley, Changlang, Lower Subansiri, Tirap, East Kameng, Kurung kumey and West Kameng.

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