

Vulnerability of Indian Coastal Agri- Ecosystem – An Approach by Vulnerability Index Assessment

S. Usha Nandhini^{1*}, V. Kavitha^{2*}, R. Thulasiram[#]

*Faculty of Agriculture,
Karunya Institute of Technology and Sciences,
Coimbatore, India.

¹ Email:sunsigeco@gmail.com

² Email: kavitha@rediffmail.com

[#]Faculty of Agriculture
Bharat Institute of Higher Education and Research
Seelaiyur, Chennai, India.
Email: thulasi.economics@gmail.com

Abstract

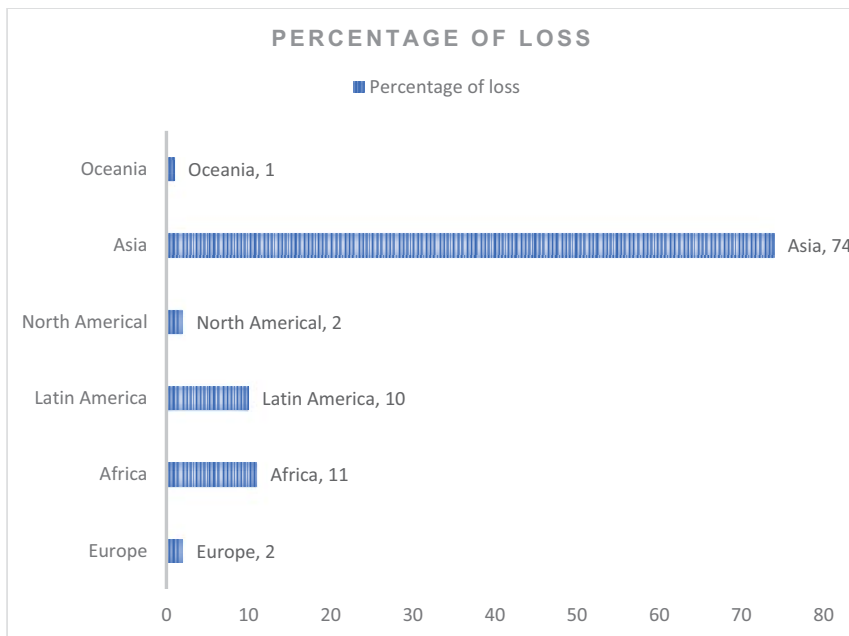
The impact of cyclone, flood and drought disasters on agriculture in Nagapattinam district has become a subject of increasing importance and the present study aims to expose the effect of cyclone, flood and drought disasters and its vulnerability on agriculture in Nagapattinam district. In this paper we assess the vulnerability of coastal farmers of Nagapattinam district to natural disasters and identify policy options to strengthen their adaptive capacity. In general, the socio-economic conditions of the small farmers in the study area were found to be poor and this is risky mainly during the disaster period. The foremost alternative for the coastal farmers in all the disaster-prone regions was government relief funds and insurance. This paper aims to study the vulnerability of the coastal farmers to disasters.

Keywords: Cyclone, Flood, Drought, Disaster, Vulnerability index

JEL Classification: Q12

1. Introduction

Disasters are highly troublesome events that cause distress, scarcity, adversity, and grievance, resulting in the panic condition of agriculture, which in turn affects supply chain marketing in agriculture and the other infrastructures. The majority of the damages in the developing countries that occur are cyclones, floods, and droughts that naturally affect agriculture. United Nations Food and Agriculture Organization report (2021) shows that the total loss is in the agricultural sector around the world is about USD 280 billion, out of which 39 percent (USD 108.5 billion) is condensed in the Least Developed Countries and Low to Middle Income Countries groups of people. Fig.1 shows that Asia alone accounts for around 74 percent of all crop and livestock production loss, about USD 207 billion. Among the disaster's drought is the most pruned disaster affects the farming community and worsening the situation to most severe.

Fig.1 Worldwide Production Loss on Crops and Livestock's due to Natural Disasters

Reference: Agriculture and Food Organisation, US, 2021

Every year, flooding and cyclone in India affect Tamil Nadu and other Indian states of Assam, Bihar, West Bengal, Gujarat, Orissa, Uttaranchal, and Maharashtra. Recently also 1.5 million people have been affected in Odisha due to the cyclone named Yaas in 2021. Loayza, et al. (2009) found that, among all the disasters, droughts and storms have negative impacts on agriculture while floods have a positive effect.

Nyong (2005) reported that farmlands and houses were ruined by erosion in the Northern and Southern parts of India and these rural farmers have more or less been rendered jobless due to the effects of these natural disasters lead to the shifting of the farmers from their living areas to other regions. According to Saldana-Zorrilla (2003), economic vulnerability creates a decrease in the income of rural farmers that affects agricultural productivity as a whole. Dinar, A. et al (1998) also in his paper suggested that farmers of developing countries will be highly prone to natural disasters due to poor land management practices and unavailability of mechanized technologies. The average expenditure of farmer households was IDR 3,869,634/month. B.Hartoyo et al (2021) in their research found that farmers' expenditure on food was 30.17% and non-food was 23.94% with a farming cost 19.42%. The excess income of around 26.47% was used as savings. Hence the objective of the study is to assess the vulnerability of the farmers during the disaster period and the expenditure pattern of farm households to determine the socio-economic status of the farmers.

Climate-related hazards affecting the agricultural sector directly impact the production as well as the livelihood of this huge population involved in the agricultural sector. The objective of the study is to assess the vulnerability of the farmers during the disaster period and the expenditure pattern of farm households to determine the socio-economic status of the farmers.

2. Methodology

Among the 13 coastal districts of Tamilnadu, the present study focuses on Nagapattinam district which was selected purposively because of the continuous exposure of the district to natural disasters such as cyclones, floods, and drought. The study was conducted in three coastal blocks of the district, namely Nagapattinam, Thalainayir, and Vedaranyam, severely affected by natural disasters. In each of the three blocks, two villages affected by the cyclone, flood, and drought respectively were identified for the study. The study population comprised of rural farmers from each of the affected six villages. From each village 30 farmers were selected, 60 farmers each from the cyclone, flood, drought region, and the total sample size was 180.

2.1 Tools of Analysis

1. Construction of Vulnerability Indices for the study area.
2. Analysis through Principal Component analysis

2.2 Empirical method: Assessment of vulnerability indices

Lan T. Jolliffe and Jorge Cadima (2016) is an adaptive data technique which is used in this study for the analysis of vulnerability in the study area, both physical and social vulnerability perspectives were integrated. The first stage of analysis of vulnerability in the present study area involved descriptive analysis of the socio-economic and environmental characteristics, particularly adaptive capacity, sensitivity, and exposure to disasters. Second, the vulnerability indices were obtained by applying Principal Component Analysis on the adaptive capacity, sensitivity, and exposure variables. Accordingly, the first component scores from the principal component analysis measured the weighted sum of scores of all variables.

The model specification is given as:

$$Vulnerability = (adaptive\ capacity) - (sensitivity + exposure) \dots\dots\dots (1)$$

The model specification is as follows:

$$VI = (A1X1j + A2X2j + \dots + AnXnj) - (An+1Y1j + An+2Y2j + \dots + An+nYnj) \dots\dots\dots (2)$$

where VI is vulnerability index, while X values are elements of adaptive capacity, and Y values are elements of exposure and sensitivity. The values of X and Y are obtained by normalization using their mean and standard deviation. For instance, $X_{1j} = (x_{1j} - \bar{x}_1) / s_1^*$; where $\bar{x}_1$ is the mean of x_{1j} across the disasters affected regions, s_1^* is its standard deviation. The whole matrix of X_{1j} appears as follows:

$$X_{ij}/Y_{ij} = \left\{ \begin{array}{cc} (X_{11} + X_{12} + \dots \dots X_{1n}) & - (Y_{11} + Y_{12} + \dots \dots Y_{1n}) \\ \vdots & \vdots \\ (X_{m1} + X_{m2} + \dots \dots X_{mn}) & - (Y_{m1} + Y_{m2} + \dots \dots Y_{mn}) \end{array} \right\} \dots (3)$$

The i and j in the above notation implies the number of rows (disasters affected regions) and the number of columns (in this case variables of adaptive capacity, exposure, and sensitivity respectively). In equation 3.2, the A values are the first component score of each variable computed using Principal Component Analysis in STATA. Finally, the vulnerability index of each location is obtained using Eq.3.4:

$$VI = \begin{pmatrix} A_1 \\ A_2 \\ \vdots \\ A_n \end{pmatrix} \times \begin{pmatrix} (X_{11} + \dots + X_{1n}) & - (Y_{11} + \dots + Y_{1n}) \\ \vdots & \vdots \\ (X_{m1} + \dots + X_{mn}) & - (Y_{m1} + \dots + Y_{mn}) \end{pmatrix} \dots (4)$$

For the construction of vulnerability indices, indicators of adaptive capacity, which are positively associated with the first principal component, and all the indicators of sensitivity and exposure that are negatively associated with the first principal component were selected. However, in constructing the indices, the scale of analysis is important. For this study, the scale of analysis was village level.

3.Results

Table 1. Farmers perception on disaster vulnerability over the years
(n per cent)

Frequency of events	Cyclone Region		Flood Region		Drought Region	
	Increased	Decreased	Increased	Decreased	Increased	Decreased
Cyclone	92	8	16	84	13	87
Flood	96	4	98	2	0	100
Drought	57	43	72	28	89	11

As seen from the table that more than 90 percent of the respondents felt that the frequency of cyclones and floods have increased in recent years in the study area which was almost drought-free in the cyclone regions. However, though the study area had faced a continuous cyclonic period the tsunami-induced cyclone during 2004 was the worst in the memory of people which affected almost the entire coastal area. In the flood region, though 98 percent of the respondents felt increased incidence of the flood, some of them mentioned that the intensity has reduced mainly due to the construction of embankments and three fourth of the respondents said that the frequency of flood has increased significantly in recent years due to the low-lying area of the farmland in the study area. Similarly, in the drought region, 89 percent of the respondents felt the decline in rainfall that led to drought while 11 percent of the respondents felt that not only there has been a secular decline in the quantity of rainfall but also the pattern of rainfall has become erratic. The coastal farmers who live with natural disasters expressed that not only the frequency, but the intensity of the events had increased over the years.

3.1 Assessing the vulnerability of farm households to Disasters

The Vulnerability Index in the present study uses the integrated assessment approach to analyze the vulnerability of farm households to disaster variability which mainly focuses on the economic status of individuals or social groups. According to IPCC, Vulnerability is understood as a function of three components exposure, sensitivity, and adaptive capacity. In the present study, the vulnerability index was estimated with 18 subcomponents and their values are presented in Table 2. The subcomponents were normalized by using their mean and standard deviation and the normalized values are given in Table 2. From the indexed sub-component values, the major component values were worked out and the results are presented in Table 3.

From the major component values, the household vulnerability index was estimated for all the three blocks selected and the results are presented in Table 3.

Adaptive capacity: Adaptive capacity mostly depends on a number of resources that constitute the asset base forms the foundation for initiating adaptation. It could be observed from table 3 . that the major components of adaptive capacity were indicated by wealth / financial capital like livestock ownership, income from crop cultivation income from non-farm sources, size of the farm holding and cropping intensity, growing of tolerant varieties' availability of institutional support, livelihood strategy, the potential for irrigation and literacy rate. Cropping intensity, adoption of tolerant varieties, and access to credit were higher in the cyclone region, whereas the other subcomponents except farm holding size were found to be higher in the Vedaranyam block.

Table 2 Normalized index subcomponent for the study area

Major Component	Sub-Components	Standard Deviation	Mean	Normalized value		
				Cyclone Region	Flood Region	Drought Region
Adaptive Capacity	Livestock ownership	22.63	55.55	-1.06	0.12	0.93
	Non-farm income	9942.7	20910	-0.29	-0.82	1.11
	Farm income	6204.36	-25084	-0.06	-0.97	1.03
	Farm holding size	2.33	0.26	0.74	-1.14	0.4
	Cropping intensity	31.15	109.71	1.14	-0.39	-0.74
	Adoption of tolerant variety	6.01	28.33	-1.11	-0.83	0.28
Sensitivity	Access to credit	7.64	93.33	0.87	0.22	-1.09
	Illiterate sample respondents	3.47	2.78	-0.32	-0.8	1.12
	Dependence solely on agriculture as a source of income	8.08	78.67	-1.07	0.16	0.91

	Percentage of households with well irrigation	0	0	0	0	0
	Percentage of households buying well water	0	0	0	0	0
	No. of crops cultivated by respondents	0.58	1.67	0.58	-1.15	0.58
	Share of cultivable waste to the total land area	3.83	4.87	0.82	0.3	-1.11
	Percentage of households that do not stock crop produce	3.51	18.67	0.95	-1.04	0.09
	Percentage of households that utilize a natural water source	0	100	0	0	0
Exposure	Cyclone period	1.53	3.33	-0.87	-0.22	1.09
	Flood period	2.31	2.67	1.15	0.58	-0.58
	Drought period	1.53	2.33	1.09	-0.22	-0.87
	Variation in monthly rainfall	15	139.51	1.03	-0.97	-0.06

Adaptive Capacity:

The overall adaptive capacity score was positive in cyclone region (0.047) and in drought region (0.323) block and negative in flood region (-0.270) block (Table 2). Though the overall score of adaptive capacity found to be positive in cyclone region, individual sub-component values like livestock ownership and non-farm income sources which have a dominant role next to agriculture are found to be low .

In general, improving the adaptive capacity has an indirect effect on improving the sensitivity of the coastal farmers. Creating opportunities for non-farm income in all three blocks reduces the dependence of the farming communities on agriculture, thereby reducing their sensitivity to natural events. In the present study normalized value of non-farm income was high in the drought region (1.11) which shows that the opportunity to seek non-farm employment in this block is higher than in other regions.

Sensitivity: Sensitivity is basically the biophysical effect of climate change, and it can be altered by socio-economic changes. In the agricultural sector sensitivity to climate-induced disaster, variability was measured by food and water scarcity.

Table 2 shows that number of crops cultivated was higher in the cyclone regions and drought regions. Also, in all three blocks, all the farm households reported using a rainwater source. Apart from this the share of cultivable waste (8 ha) and the household that don't stock the product was found to be higher in the cyclone regions (22 percent). The overall sensitivity score for all three regions was found to be

negative accounting for -0.035 in the cyclone region, 0.098 in the flood region, and -0.277 in the drought region (Table 2).

This implies that cyclone regions and flood regions are more sensitive to natural disasters. Natural resource-based income like agriculture, livestock management will also increase the sensitivity of the households as they are highly dependent on climatic condition while the non-farm income sources may reduce the sensitivity as the return from non-farm activities are higher than on-farm activities during the disaster period.

Exposure: Exposure is defined as a degree of climate stress upon a particular unit of analysis; it may be represented based on the average reported number of cyclones, floods, and drought events over the past five years and mean and standard deviation of monthly average rainfall. The cyclone region is highly vulnerable because the region is located in the coastal area whereas the flood region is highly vulnerable because the farmland was located in the low-lying area. The overall exposure score for cyclone region is (0.603), flood region is (-0.383) and drought region is (1.340) block (Table 2).

3.1 Vulnerability Index

In order to quantitatively assess the overall vulnerability index, Principal Component Analysis (PCA) (Ognjen Zurovec et al., 2007) was run using statistical software (STATA) for the 18 indicators listed in Table.3 Eighteen components were extracted in the first stage of the PCA but only the first six were significant based on the Eigenvalue criterion being greater than 1.

Table 3 Factor scores from principal component analysis and associated statistics

Indicator	Components	Eigen value	Proportion	Cumulative	Scoring Factor: PCA1
Adaptive Capacity	Livestock ownership	3.2538	0.2034	0.2034	-0.081
	Non-farm income	1.9845	0.1240	0.3274	-0.153
	Farm income	1.3862	0.0866	0.4140	-0.129
	Farm holding size	1.3236	0.0827	0.4967	-0.074
	Cropping intensity	1.1693	0.0731	0.5698	-0.043
	Adoption of Tolerant variety	1.0505	0.0657	0.6355	-0.094
	Access to credit	0.9908	0.0619	0.6974	0.004
	Illiterate sample respondents	0.9269	0.0579	0.7553	0.004
	Dependence solely on agriculture as a source of income	0.8857	0.0554	0.8107	0.09
	Percentage of households with well irrigation	0.00	0.00	0.00	0.00
	Percentage of households buying well water	0.00	0.00	0.00	0.00
Sensitivity	No.of crops cultivated by respondents	0.8631	0.0539	0.8646	-0.20

	Share of cultivable waste to the total land area	0.7712	0.0482	0.9128	0.16
	Percentage of households that do not stock crop produce	0.6918	0.0432	0.9561	0.172
	Percentage of households that utilize a natural water source	0.00	0.00	0.00	-0.073
Exposure	Cyclone period	0.6234	0.0390	0.9950	-0.528
	Flood period	0.0794	0.0050	1.0000	0.462
	Drought period	-0.0000	-0.0000	1.0000	0.533
	Variation in monthly rainfall	-0.0000	-0.0000	1.0000	0.306

The first principal component explained a larger variation (20.34 percent), the second principal component explained 12.40 percent, the third and fourth components explained 0.08 percent each, fifth and sixth components explained 0.07 and 0.06 percent of the variation. Hence, the first component factor score was used to construct the vulnerability index, as it explained the majority of the variation. The weights (or scores) assigned to the indicators on the first component were -0.081, along with their associated statistics. It could be observed from table 3. that the factor scores, the scoring factor of the first principal component was positively and negatively associated with the indicators. Thus, for the construction of the vulnerability indices, indicators of adaptive capacity were positively associated with the scoring factor of the first principal component, and all the indicators of sensitivity and exposure which were negatively associated with the scoring factor of the first principal component were taken. Higher values of the vulnerability index would show less vulnerability and vice versa. This is because, adaptive capacity was considered to be positively contributing to the reduction of vulnerability, while exposure and sensitivity were negatively contributing to vulnerability reduction. Based on the formula for vulnerability index given in the methodology, the vulnerability index of each region was calculated based on the normalized value of each indicator as well the weights or scores assigned to the indicators as shown in table 3. It is evident from table 4 that the net effect of adaptive capacity was positive in cyclone and drought regions. Sensitivity was negative in cyclone and drought regions and Exposure was found to be positive in cyclone and flood regions.

Table 4. Index of major components and overall vulnerability index

S. No	Indicator	Cyclone region	Flood region	Drought region
1	Adaptive Capacity	0.047	-0.270	0.323
2	Sensitivity	-0.035	0.098	-0.277
3	Exposure	-0.603	0.029	-0.75
	Vulnerability Index	-0.591	-0.397	1.35

Farmers in the cyclone and flood regions are highly vulnerable to natural disasters. The vulnerability of cyclone region was mainly associated with lack of livestock ownership (-1.06), non-farm income (-0.29), lower level of literacy rate (-0.32), farmers mainly dependent on agriculture as a source of income (-

1.07), high frequency of cyclone (-0.87) Similarly, the vulnerability of the flood region was attributed to lower farm (-0.97) and non-farm income source (-0.82), low cropping intensity (-0.39), low farm holding size (-1.14), less number of crops cultivated (-1.15), less amount of stock holding (-1.04) and increased incidence of flood occurrence (0.58). Vulnerability of flood region was associated with Livestock ownership (0.93), increased non-farm income (1.11) stabilization of farm income (1.03), agriculture as the main source of income (0.91), and a higher number of crops cultivated (0.58).

4 Consumption Expenditure on Family households

Farmers' household incomes are closely related to the income of the farmers. If the income of the farmer increases, then naturally it increases the expenditure on family consumption and vice versa. The consumption pattern of the family households is given in the table. for all the three zones, so that the socio-economic status of the farmers is seen undoubtedly.

Table 4 Consumption Pattern of Farm Households

S. No	Particulars	(Amount spent (Rs/yr))		
		Cyclone Region	Flood Region	Drought Region
1	Food Items	11520 (68.25)	17880 (77.95)	17040 (77.14)
2	Medical	850 (5.04)	744 (3.24)	400 (1.81)
3	Education	2400 (14.21)	2714 (11.83)	2800 (12.68)
4	Cloths and Festival	2110 (12.50)	1600 (6.98)	1850 (8.37)
Total		16880 (100.00)	22938 (100.00)	22090 (100.00)

Table 4 shows the consumption pattern of farm households. Expenditure on food items was found to be higher in the flood region which accounts for 77.95 percent followed by the drought region 77.14 percent and cyclone region 68.25 percent. Apart from that expenditure on education was found to higher with the percentage share of 14.21 in cyclone region, 11.83 in flood region and 12.68 percent in drought region and shows farmers in cyclone region spends more than other regions due to the fact that, as the region is close to Nagapattinam town, the households' items are bit costlier than other regions and hence expenditure were also found to be higher.

Table.5 Size Distribution of the farmers

S. No	Particulars	Cyclone region		Flood region		Drought region	
		No. of farmers	Area operated	No. of farmers	Area operated	No. of farmers	Area operated
1	Small (1.01-2.0)	57 (95.00)	53.56 (83.21)	50 (83.33)	74.80 (59.75)	53 (88.33)	79.60 (62.19)
2	Medium (2.01-5.0)	3 (5.00)	10.80 (16.79)	6 (10.00)	18.40 (14.69)	3.0 (5.00)	16.40 (12.81)
3	Large (>5.0)	0	0	4 (6.67)	32 (25.56)	4.00 (6.67)	32.00 (25.00)
4	Total	60 (100.00)	64.36 (100.00)	60 (100.00)	125.2 (100.00)	60 (100.00)	128 (100.00)

Size of the farm is also directly affecting the socio-economic status of the farm house holds which simultaneously shows the impact on expenditure. From the table, it is noted that out of the total sample size in the cyclone region, it could be seen from table 5.10. that 57 numbers of small farmers had operated 83.21 percent of the area and only three numbers of medium farmers owned 16.79 percent of the total operated area. There exist no large farmers.

In the flood region, out of the total sample size, 50 numbers of farmers fall under the category of small farmers and the area operated was 59.75 percent. Medium farmers and large farmers were six and four in numbers operating an area of 14.69 percent and 25.56 percent, respectively.

Similarly in the drought region, small farmers were 53 in numbers, and they had 62.19 percent of the operated area whereas three medium farmers and four large farmers possessed 12.81 percent and 25 percent of the operated area.

This shows that small farmers were high in all three regions when compared to medium and large farmers. In general, the socio-economic conditions of the small farmers in the study area were found to be poor and this is risky mainly during the disaster period. This situation could lead not only to a loss in farm produce but a total loss in income of the rural farmer during the occurrence of natural disasters and moreover poor farmers may not be able to withstand the effect of natural disasters. The size of the farm also plays a major role in adopting new technologies during disaster events.

5. Discussion and Conclusion

It could be concluded that the farmers in the cyclone and flood regions were highly vulnerable to natural disasters and drought region farmers are less vulnerable compared with the other two regions. The way to reduce the vulnerability is to decrease sensitivity and to increase adaptive capacity. Creating other job opportunities would decrease sensitivity to disaster events. To increase adaptive capacity, adaptive strategies such as repairing and building reservoirs in cyclone and flood regions, irrigation and water storage in drought regions, implementing disaster-need agricultural practices like increasing crop diversification will reduce the vulnerability of the farming community. The ultimate impact of a natural disaster on a household depends on the household's vulnerability to its effects. Agricultural failure and further reduction in the income level during the disaster period makes the farmers engage with several other income generating opportunities through non-farm income source. Though the non-farm income source supports financially, severity of heavy rain, flood or cyclonic event during that period reduces the days of employment, simultaneously reduces the level of income. The foremost alternative for the coastal farmers in all the disaster-prone regions was government relief funds and insurance. Otherwise, it will lead to a negative impact on their livelihood since the farmers will be forced to take income management measures like availing bank loans, borrowing from money lenders, borrowing money from friends and relatives, hypothecation of assets, and jewelries'.

6. REFERENCES

1. *Agriculture and Food Organisation*, 2021, US.
2. B Hartoyo et al., 2021, *Analysis of income and expenditure of farmers' household in the rain-fed area of Boyolali district*: Earth Environ. Sci. IOP conference paper.
3. Department of Economics and Statistics, 2011. *Season and Crop Report of Tamil Nadu*.
4. Deressa, et al., 2008. *Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia: IFPRI, Discussion Paper 00798*, Washington, DC: International Food Policy Research Institute.
5. Dinar, A. et al, 1998. *Measuring the impact of climate change on Indian agriculture: World Bank Technical Paper 402*, Washington, DC.
6. <https://floodlist.com/asia/india-cyclone-yaas-may-2021>
7. Loayza, et.al. 2009. *Natural Disasters and Growth Going beyond the Averages: Policy Research Working Paper 4980*, The World Bank East Asia, and Pacific Social Protection Unit and Development Research Group, 40.
8. Lan T. Jolliffe and Jorge Cadima, 2016 .Principal Component Analysis: a review and Recent Developments ,Philosophical Transactions of the Royal Societies ,A 374: 20150202.
9. Nyong, A. 2005. *Adaptation of root crop farming system to climate change in Ikwerre local government area of River state*: Nigeria.
10. Ognjen Zurovec et al., 2017, *Quantitative Assessment of Vulnerability to Climate Change in Rural Municipalities of Bosnia and Herzegovina*, Sustainability 9(7):1208.
11. Saldana-Zorrilla, 2009. *Impact on climate- related disasters on human migration in Mexico: spatial model*, Climate Change 96(1):97-118
12. *The Intergovernmental Panel on Climate Change (IPCC) Report*, 2007. US