Impact of Global Warming on Rainfall, And Cotton Lint With Vulnerability Profiles of Five Districts In Vidarbha, India

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Abstract:- India is an agriculture based country and sixty five per cent of agriculture is heavily dependent on natural factors such as rainfall and temperature. India is an important grower of cotton on a global scale. Vidarbha is the eastern region of Maharashtra State. Nearly 89% of cultivated area of Vidarbha is under rain fed farming.Now a day's global warming has become a great challenge for the agrarian economy of India. This paper analyses the agriculture productivity of cotton lint, average maximum and minimum temperatures and total rainfall data for twenty two years obtained from IMD, Pune for five districts of Vidarbha. Regression and correlation analysis is obtained and their significance is tested. It is observed that 4 month average total mean rainfall shows decreasing trend for all the study districts except Wardha district. Global warming vulnerability profiles are developed at the district level for agriculture for these districts of Vidarbha region and Wardha observed as the most vulnerable district.

Keywords:- Agriculture, Climate Variables, Correlation, Regression, t-test, Vulnerability Index.

1 INTRODUCTION

Global warming/Climate change is one of the biggest threats facing the world very much impacting agriculture production all over the world. In India agriculture sector plays a vital role in overall economic and social well being of India. Agriculture is an economic activity highly dependent on natural climatic conditions. As Indian agriculture is rain fed, farmers are always trapped in a phase of continuous economic crisis. India ranks first among the rain fed agricultural countries of the world in terms of both extent (86 M ha) and value of produce. Temperature and rainfall are the key factors for agriculture production that will affect yield of rain fed crops. India ranks first among the rain fed agricultural countries of the world in terms of both extent and value of produce. Rain fed agriculture is practiced in two-thirds of the total cropped area of 162 million hectares. In India 65 per cent of agriculture is heavily dependent on natural factors such as rainfall, temperature, weather condition etc. In crops, cotton has been chosen purposively since cotton has prominent cash crop for Indian farmers in achieving food security and well being of the country.

2 REVIEW OF LITERATURE

Now a day's Global warming becomes an alarming threatening issue of concern in the developing world like India. Global warming is the increase in the average temperature of the Earth's near surface air and oceans since the mid-twentieth century and its projected continuation. N.H.Ravindranath *et.al*. [9] studied climate change modeling for India and showed the Indian sub-continent is likely to experience a warming of over 3-5^{0}C and significant changes in flood, drought frequency and intensity.

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NATCOM [8] projected that by the end of the 21st century rainfall over India will increase by 15-40%, and mean annual temperature will increase by 3-6^{0}C. IPCC [6] suggested that global temperature will increase by 1.8^{0}C to 4^{0}C with an overall average increase of 2.8^{0}C in temperature. Shafiqur Rahman [13] observed that Agriculture production depends on rainfall and atmospheric temperature or global warming. Vijay Gupta [16] observed the developing countries are particularly vulnerable to climate change due to their vast population depending on natural resources. The average global temperature has risen by about 0.8^{0}C from pre-industrial level. In India, monsoons are getting more variable, less predictable and very extreme. Importantly, April of the year 2010 was reported to the warmest individual month ever. Eleven of the last twelve years during 1995 to 2006 rank among the 12 warmest years in the instrumental record of global surface temperature since 1850. Analyses done by the Indian Meteorological Department (IMD) and the Indian Institute of Tropical Meteorology (IITM), Pune, generally show the same trend for temperature, heat waves, glaciers, droughts and floods, and sea level rise as by the Intergovernmental Panel on Climate Change of United Nations indicated by Raghava Reddy P.[11]. Increase in global temperature will affect the agriculture production in India. According to IPCC reports, the surface temperature of the earth has risen by 0.6 ± 0.2^{0}C over the 20th century. The increased temperature resulting from global warming is likely to reduce the profit from cotton cultivation. Eid, *et al*.[3] and Kurukulasuriya and Mendelsohn [5], assesses previous studies and concluded that the dry lands are greatly affected due to climate change. It may be noted that in the last 50 years, the rise in temperature has been 0.13± 0.07^{0}C per decade. Very recently, National Oceanic and Atmospheric Administration (NOAA), climate agency of America, reported that the average temperature of Earth for the first four months of the year 2010, of 13.3^0 C is 0.69^{0}C above the 20th century average. M.H. Fulekar, R.K. Kale[4] observed the global ocean surface temperature was 0.57^{0}C above the 20th century average of 16^{0}C. It was found that temperature increase has significant negative impact on agriculture production. Moreover; an increase in revenue was visualized with the increase in rainfall. Changing climate has threatened the productivity of agriculture sector making it vulnerable both economically and physically to climate unevenness and change. Usman Shakoor, *et.al* [15] observed the overall extent of negative impact of temperature is greater than the positive effect of rainfall in the region. S. Angles *et al* [12] studied rainfed agriculture supports 40 per cent of the India's population and contributes 44 per cent to the national food basket. These studies motivate us to study statistically the changes in temperature, rainfall, and agriculture production of cotton in Amravati, Akola, Buldana, Yavatmal and Wardha districts of Vidarbha region. This paper analyzes statistically the atmospheric temperature, rainfall and agriculture production data of cotton lint for Amravati, Akola, Buldana, Yavatmal and Wardha districts, during the study period 1988 to 2009. The main objectives of the study are to introduce a quantitative approach for assessing the vulnerability of agriculture in these districts by developing a vulnerability index.

3 STUDY AREA

Recently, Vidarbha region has become infamous for a large number of farmer suicides occurring. The region comprises eleven districts of which Amravati, Akola, Washim, Buldana, Yavatmal and Wardha districts are the most distressed districts of Vidarbha for which the Government of India and Government of Maharashtra State have announced the package of relief for the farmers. Vidarbha's economy is primarily agricultural and it is less economically prosperous as compared to the rest of Maharashtra. Vidarbha is the eastern region of Maharashtra State made up of Nagpur division and Amravati division. Geographical area of Vidarbha is 93.43 lakh ha of which 60.62 lakh ha is cultivable area. The cultivable area for five study districts is 42.12 lakh ha. During 2004-05, the area under cotton for five districts was 11.07 lakh ha, from the data of Department of Agriculture, Govt. of Maharashtra, India.

4 MATERIALS AND METHODS

The data used in this paper are the yearly averages of total mean rainfall, minimum and maximum atmospheric temperatures. The data for total 22 years are obtained for the years 1988-2005 by the India Meteorological Department, Pune and for 2005-2009 are downloaded from www.imdpune.gov.in under the link of Hydrology. Also year wise secondary data for area, production, and yield of cotton for Amravati, Akola, Buldana, Yavatmal and Wardha districts are obtained from 'Epitome of Agriculture- Part I and Part II' published in 2004-05 by State Agriculture Department, Mumbai and data from 2005-2009 are collected from Divisional Agricultural Department, Amravati. Correlation analysis and regression analysis is applied to production data as well as to temperature and rainfall data. The p-values are obtained and tested at 5 per cent level of significance. Temperature, rainfall and agriculture production data of cotton are made over the years i.e. time and therefore are referred to as time series data, which is defined as a series of observations that varies over time. The time series is made up of four components known as seasonal, trend, cyclical and irregular (Patterson, [10]). Trend is defined as the general movement of a series over an extended period of time or it is the long term change in the dependent variable over a long period of time (Webber and Hawkins, [18]). Trend is determined by the relationship between the two variables as temperature and time, rainfall and time, and agriculture production and time. The statistical methods such as regression analysis, correlation, and coefficient of determination (Murray R. Spiegel, Larry J. Stephens, [7]), t-test and p-values are used.

4.1 Linear Regression

The linear regression line was fitted using the most common method of principle of least squares. This method calculates the best fitting line for the observed data by minimizing the sum of the squares of the vertical deviations from each data point to the line. If a point lies exactly on the straight line then the algebraic sum of the residuals is zero. Residuals are defined as the difference between an observation at a point in time and the value read from the trend line at that point in time. A point that lies far from the line has a large residual value and is known as an outlier or, an extreme value.

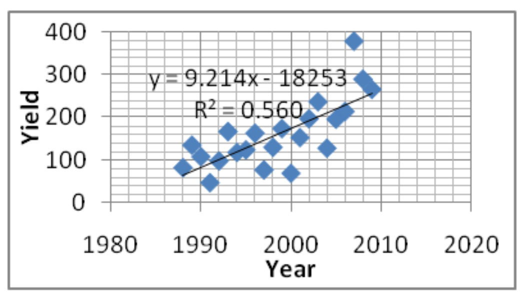
The equation of a linear regression line is given as:

$$\mathbf{y = a + b\,x,}$$

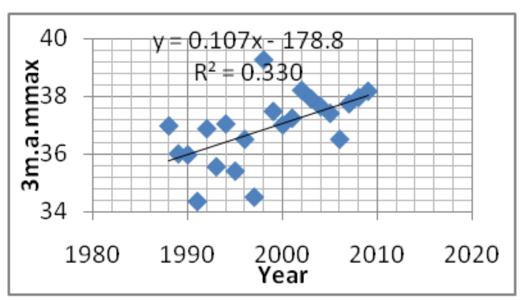
where, **y** is the observation on the dependent variable, **x** is the observation on the independent variable, **a** is the intercept of the line on the vertical axis, and **b** is the slope of the regression line. In order to fit regression lines scatter diagrams of the annual average temperature, rainfall and yield of cotton lint (dependent variables) against time (independent variable) in years were plotted. Linear regression lines were then fitted to determine the trends of temperature, rainfall and yield of cotton lint. The drawing of the scattered diagrams and the fitting of the regression lines were done in Microsoft Excel.

4.2 The scatter diagram and the trend line for various variables of study districts are shown below:

4.2.1 Buldana district:



(a)



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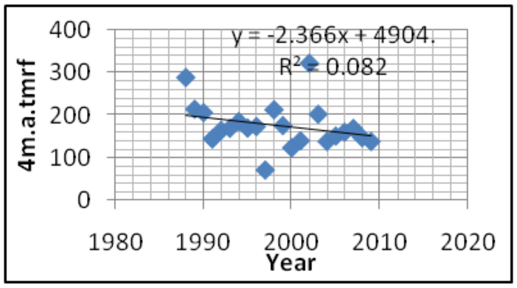

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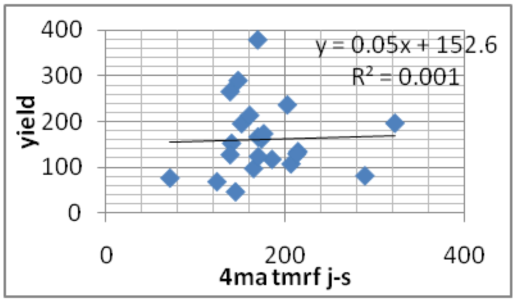
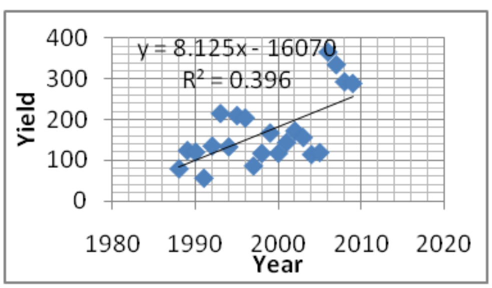


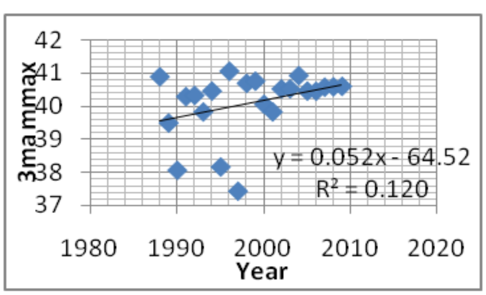
(d)

The above diagram (a) and (b) indicate the trend line for yield of cotton lint, 3 m.a. mmax temperature against time is increasing, which implies there is a positive linear relationship between yield of cotton yield and time, and between 3ma mmax temperature and time, the diagram (d) indicate low positive relationship between yield of cotton yield and 4ma tmrf. Further diagram (c) indicate the trend line for 4ma tmrf against time shows decreasing trend implies the negative relationship between them.

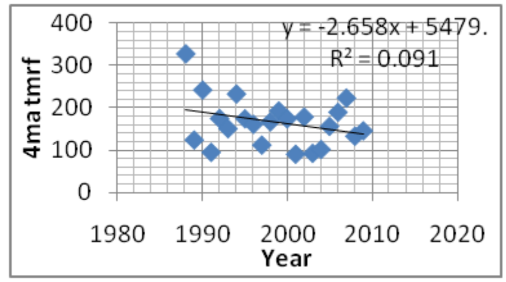
4.2.2 Akola district:



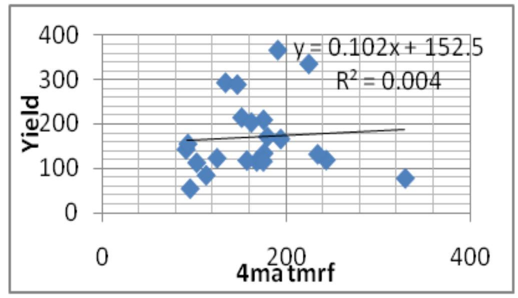
(a)



(b)



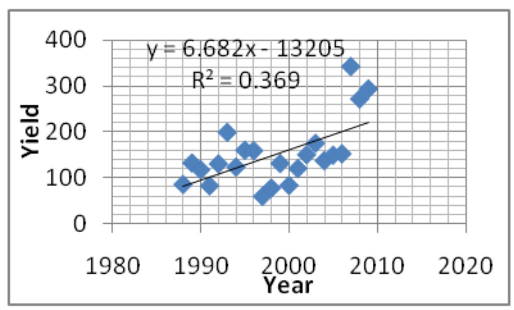
(c)



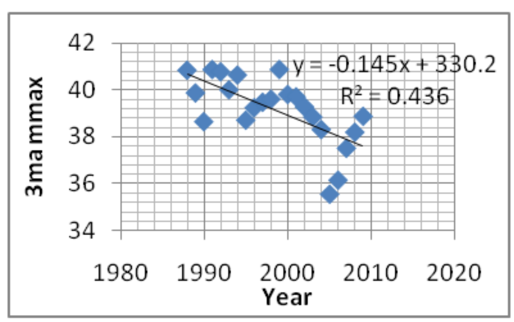
(d)

The above diagram (a), (b),and (d) indicate the trend line for yield of cotton lint, 3ma mmax temperature against time is increasing implies positive relationship between them whereas yield of cotton lint and 4ma tmrf indicate negative relationship. The diagram (c) indicates decreasing trend line implies negative relationship between 4ma tmrf and time.

4.2.3 Amravati district:



(a)



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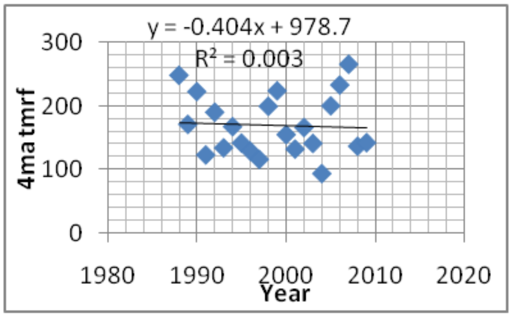

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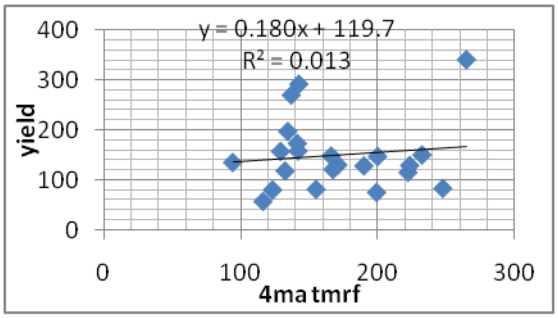
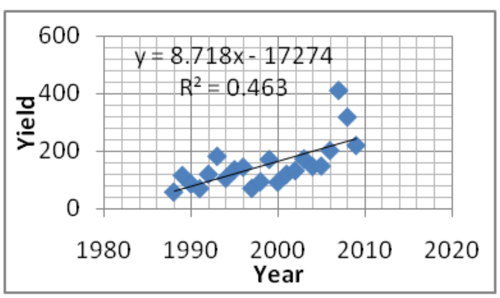


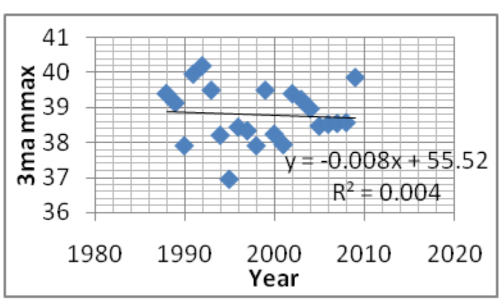
(d)

The above diagrams (a) and (d) indicates the trend line for yield of cotton lint against time,and yield of cotton lint against 4ma tmrf is increasing indicating positive relationship between them. The diagrams (b) and (c), indicates trend line for 3ma mmax temperature against time, 4ma tmrf against time is decreasing shows negative relationship between them.

4.2.4 Yavatmal district:



(a)



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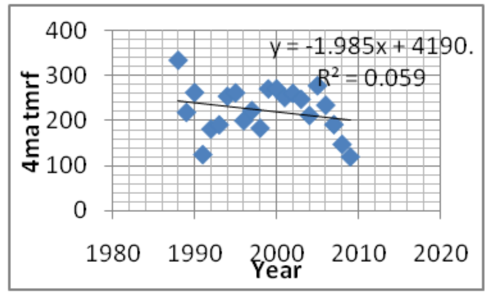

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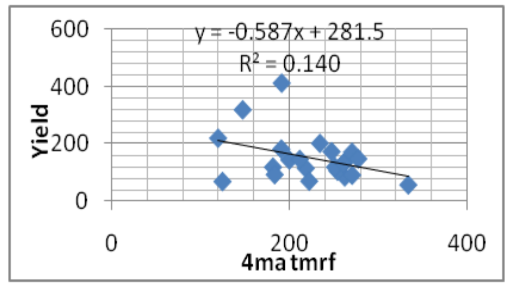
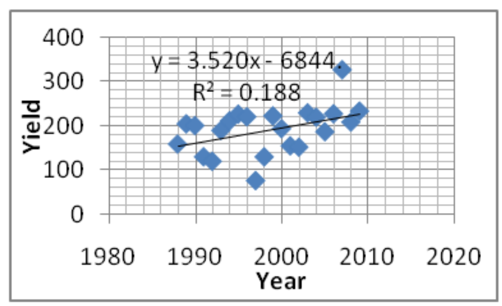


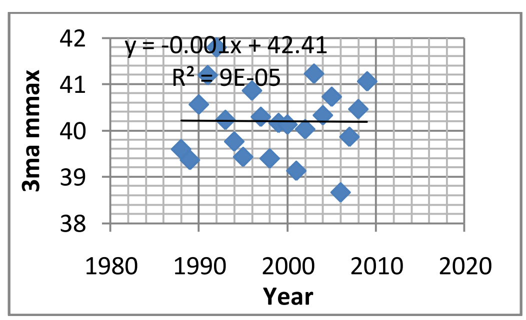
(d)

The above diagram (a) indicates the trend line for yield of cotton lint against year is increasing shows positive relationship. The diagram (b) and (c) indicate negative relationship between 3ma mmax temperature and time, and 4ma tmrf and time indicating decreasing trend line whereas (d) indicates negative relationship between yield of cotton lint and 4ma tmrf.

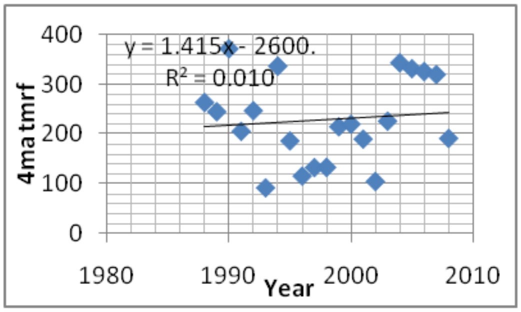
4.2.5 Wardha district:



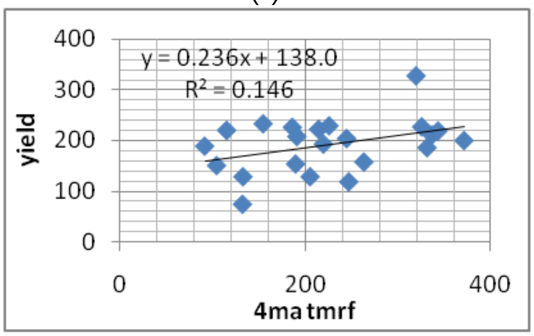
(a)



(b)



(c)



(d)

The above diagram (a), (d), and (c) indicates the trend line for yield of cotton lint and 4ma tmrf against time is increasing, which implies there is a high positive linear relationship between yield of cotton lint and time whereas (d) indicate a positive relationship between yield of cotton lint against 4ma tmrf. The diagram (b) shows weak negative relationship between 3ma mmax temperature and time.

Table No.(2): Table of regression coefficients for various regression lines for study districts are as follows:

	Regression coefficients b			
District	**4ma tmrf-time**	**Yield-time**	**Yield-4ma tmrf**	**3ma mmax-time**
Buldana	-2.366	9.214	0.05	0.107
Akola	-2.6586	8.1259	0.102	0.052
Amravati	-0.4048	6.6827	0.1802	-0.145
Yavatmal	-1.9852	8.7188	-0.5877	-0.008
Wardha	1.4157	3.5206	0.2368	-0.001

The most negative(-2.6586) regression coefficiet observed for 4ma tmrf against time indicating 4ma tmrf is decreases by 2.6586 mm per year for Akola district. Further yield of cotton lint is increases by 9.214 kg per hectar over the years for Buldana district. Yield of cotton lint is decreases by 0.5877kg.per hectar over 4ma tmrf for Yavatmal district whereas it is increases for Wardha, Amravati,Akola and marginal increase for Buldana districts.

4.2 Correlation Coefficient

The correlation coefficient determines the magnitude and strength of linear relationship between the two variables under study. It always lies between –1 to +1. The value +1 indicating a perfect positive correlation and the value -1 indicating a perfect negative correlation (means all points would lie along a straight line and having a residual of zero). A correlation coefficient close to or equal to zero indicates no or very poor relationship between the variables. A positive correlation coefficient indicates a positive (upward) relationship and a negative correlation coefficient indicates a negative (downward) relationship between the variables. The strength of linear relationship between the variables and time are calculated to determine the trend of temperature, rainfall and agriculture production and it is measured by the correlation coefficient. The correlation coefficients between temperature, rainfall, agriculture production and time were calculated as follows.

Given the pairs of values (x_1,y_1), (x_2,y_2), ………………(x_n,y_n), the Karl Pearson's formula for calculating the correlation coefficient 'r' is given by:

$r=\sum (xi-\bar{x})\ (yi-\bar{y})\ /\ \sqrt{\sum (xi-\bar{x})^2 \sum (yi-\bar{y})^2}$,
i=1,2,………..n.

4.3 Testing the significance of the correlation coefficient

In testing the significance of the correlation coefficient, the following null (H_0) and alternative (H_1) hypothesis were considered.

Hypothesis: $H_0: \rho=0$ against $H_1: \rho\neq 0$

Where, ρ is the population correlation coefficient.
The appropriate test statistics for testing the above hypothesis is

$t = r \sqrt{(n-2)}\ /\ \sqrt{(1-r^2)}$,
d. f. = n-2 = 20

Significant value for t at 5% level = 2.086

The following table represents the values of the correlation coefficients and the test statistics represented within the bracket.

Table No.(3): Table of Correlation coefficients and t values

	$r(x_1,x_2)$	$r(x_1,x_3)$	$r(x_2,x_3)$
Buldana	0.523525 (2.74794) **Significant**	0.033492 (0.149866) Insignificant	0.3424177 (1.629868) Insignificant
Akola	0.206366 (0.9432) Insignificant	0.06949 (0.311524) Insignificant	0.088404 (0.396909) Insignificant
Amravati	-0.41374 (-2.03244) Insignificant	0.117694 (0.530029) Insignificant	-0.179224 (-0.814 Insignificant 7)
Yavatmal	0.0344424 (0.154041) Insignificant	-0.37464 (-1.80704) Insignificant	-0.339667 (-1.61506) Insignificant
Wardha	-0.13805 (-0.62334) Insignificant	0.382695 (1.852486) Insignificant	-0.091771 (-0.41215) Insignificant

Note: Parenthesis indicates the t values.

The above table shows the correlation coefficients between the variables as temperature, rainfall, and the yield of cotton lint. The highest positive correlation (0.523525) is observed between the yield of cotton lint(x_1) and 3ma mmax temperature(x_2) showing significant relationship for the Buldana district whereas highest positive correlation (0.382695) is observed between the yield of cotton lint(x_1) and 4ma total mean rainfall(x_3) showing insignificant correlation for Wardha district. Also highest positive correlation (0.3424177) is observed between 3ma mmax temperature and 4ma total mean rainfall for Buldana district. The highest negative correlation is seen between yield of cotton lint and 3ma mmax temperature for the Amravati district whereas the most negative relationship between the yield of cotton lint and 4ma total mean rainfall is observed revealed insignificant relationship for Yavatmal district . Further the most negative relationship between 3ma mmax temperature and 4ma total mean rainfall observed for Yavatmal district indicating insignificant relationship.

4. 4 Calculating p-value

The p-value for a test of hypothesis is defined to be the smallest level of significance at which the null hypothesis is rejected.

The p-values were calculated in the following manner.

p-value= P(t> Observed value of the test statistic)

= 1- P(t≤ Observed value of the test statistic)

For t_{20}= 2.74794, p= 1- P(t≤ 2.74794)

= 1- 0.99311= 0.00689

As p-value is less than 0.05, the null hypothesis is rejected and conclude that the correlation coefficient between yield of cotton lint and 3ma mmax temperature is highly significant for Buldana district. The rest of the correlation coefficients are insignificant.

5 VULNERABILITY: AN INDEX APPROACH

The word 'vulnerability' is usually associated with natural hazards like flood, droughts, extreme heat, extreme cold, sea level rise, cyclones, storms, depressions and social hazards like poverty, inequality etc. It is extensively used in climate change literature to denote the extent of damage a region is expected to be affected by various factors which are affected by climate change. In the context of climate change or global warming there are many studies on vulnerability and its definitions vary according to the perception of the researchers. A study by Intergovernmental Panel on Climate Change (IPCC), links vulnerability with climatic change, and point out that the vulnerability of a region depends to a great extent on its wealth and that poverty limits adaptive capabilities (IPCC, 2000). Further, they argue that socio-economic systems "typically are more vulnerable in developing countries where economic and institutional circumstances are less favorable". As per the IPCC Third Assessment Report vulnerability is defined as "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity". Unmesh Patnaik and K.Narayanan[14] observed vulnerability is often reflected in the condition of the economic system as well as the socioeconomic characteristics of the population living in that system. In literature, quantitative assessment of vulnerability is usually done by constructing a 'vulnerability index'. This index is based on several set of indicators that result in vulnerability of a region. It produces a single number, which can be used to compare different regions. The vulnerability index is a formative measurement and the indicators chosen need not have internal correlation. Here index number is used in the ordinal sense i.e. on the basis of this index different regions are ranked and grouped to be relatively less or more vulnerable. It is constructed in such a way that it always lies between 0 and 1 so that it is easy to compare regions. Sometimes the index is expressed as a percentage by multiplying it by 100.

The vulnerability index is obtained as follows:

Let Xij be the value of the indicator j corresponding to district i , i= =1,2……M; j=1,2….K.

Here M=5, K=3

The normalized score are by using formula,

xij = [Xij- min{Xij}] **/** [max{Xij}-min{Xij}]

The simple average of all normalized scores to give the vulnerability index. Then the vulnerability indices are used to rank the different districts in terms of vulnerability. A district with highest index is said to be most vulnerable and is given the rank 1, the district with next highest index is assigned rank 2 and so on.

Table No.(1): Year wise data for twenty two years in study districts

	Buldhana			Akola			Amravati			Yavatmal			Wardha		
Year	Yield cottonlint	3ma mmax	4ma tmrf	Yield cottonlint	3ma mmax	4ma tmrf	Yield Cottonlint	3ma mmax	4ma tmrf	Yield cottonlint	3ma mmax	4ma tmrf	Yield cottonlint	3ma mmax	4ma tmrf
1988	82	36.97	289.63	78	40.90	329.25	84	40.83	247.88	57	39.40	333.95	158	39.60	263.55
1989	135	36.00	**214.55**	123	39.50	125.18	131	39.87	171.18	115	39.13	218.30	204	39.37	244.95
1990	108	35.97	206.65	119	38.07	243.55	116	38.63	222.40	85	37.90	262.33	200	40.57	371.85
1991	47	34.35	144.35	55	40.30	95.95	81	40.87	123.35	69	39.97	124.38	129	41.20	205.40
1992	98	36.87	164.60	134	40.33	175.95	129	40.77	190.15	119	40.20	181.35	119	41.80	247.15
1993	167	35.55	169.45	214	39.83	151.90	198	40.00	134.55	182	39.50	190.80	189	40.23	91.47
1994	118	37.03	185.33	132	40.47	234.20	122	40.63	167.60	105	38.20	254.08	211	39.77	336.93
1995	124	35.40	170.00	209	38.17	175.50	159	38.70	142.00	135	36.93	261.70	226	39.43	186.20
1996	163	36.50	173.65	203	41.07	162.28	158	39.23	129.20	144	38.43	199.85	220	40.87	115.23
1997	77	34.50	70.80	85	37.43	113.20	58	39.47	116.40	70	38.33	222.20	75	40.30	132.40
1998	130	39.25	213.27	116	40.70	168.20	76	39.60	199.47	93	37.90	183.25	129	39.40	132.88
1999	174	37.47	176.00	166	40.77	194.10	130	40.87	223.68	171	39.50	270.48	222	40.17	214.63
2000	69	37.00	123.50	116	40.07	175.30	82	39.80	155.15	91	38.23	270.58	193	40.13	219.80
2001	153	37.23	140.00	143	39.83	91.50	119	39.70	132.53	119	37.93	251.25	154	39.13	189.75
2002	197	38.20	323.25	171	40.53	179.63	149	39.27	166.25	132	39.40	260.68	151	40.03	104.33
2003	237	37.90	202.53	155	40.53	93.58	174	38.83	141.45	173	39.23	247.45	229	41.23	225.88

2004	128	37.63	138.35	113	40.93	102.93	136	38.30	94.20	146	38.97	211.60	219	40.33	343.60
2005	196	37.40	151.25	118	40.47	157.35	148	35.53	200.15	148	38.47	277.45	186	40.73	331.78
2006	214	36.50	160.21	365	40.46	191.00	151	36.13	232.64	202	38.52	234.29	227	38.67	325.86
2007	379	37.73	169.18	334	40.59	224.65	342	37.50	265.13	412	38.54	191.13	327	39.87	319.95
2008	290	37.95	147.25	292	40.60	134.30	271	38.18	137.03	319	38.57	147.15	208	40.47	191.15
2009	266	38.17	138.35	288	40.61	147.00	293	38.87	142.58	220	39.87	119.53	233	41.07	154.70

Note:
1)3ma mmax= Three months (March, April, May) average mean of maximum temperature in ^{0}Celcius.
2) 4ma tmrf= Four months (June, July, August, September) average total mean rainfall in mm.
3) x_1= Yield of cotton lint in Kg/hector.
4) x_2= 3ma mmax temperature.
5) x_3= 4ma tmrf.

Table No.(4): Table of Vulnerability indices and ranks of the districts are as shown below:

District	Variance in 3ma mmax temp.	Variance in 4ma tmrf	Total prod. of cotton lint	Normalised score			Sum of the scores	Vulnera bility index	Rank of district
				Variance 3ma mmax temp.	Variance 4ma tmrf	Total pro. of cotton lint			
Buldana	1.485755	2862.069	3552	0.613187	0.1359537	0.271619	1.020759	0.340253	2
Akola	0.960379	3257.902	3729	0.252477	0.2141247	0.467849	0.934451	0.311484	4
Amravati	2.049152	2173.644	3307	1	0	0	1	0.333333	3
Yavatmal	0.651274	2808.817	3307	0.040255	0.1254372	0	0.165692	0.055231	5
Wardha	0.592643	7237.322	4209	0	1	1	2	0.666667	1

6 CONCLUSION

On the basis of present investigation the trend analysis indicates that 4 month average i.e.for the month of June to September, total mean rainfall shows decreasing trend for all the study districts except Wardha district. The yield of cotton lint indicates increasing trend for all the districts. The 3ma mmax temperature shows increasing trend for Buldana and Akola districts whereas Amravati, Yavatmal, and Wardha districts indicates decreasing trend. In the present study an attempt was made to assess the vulnerability for agriculture sector for the current climatic variables. It is observed that Wardha district is most vulnerable followed by Buldana, Amravati, Akola, and Yavatmal.

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