International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2024; SP-9(1): 01-07

https://www.mathsjournal.com
Received: 02-11-2023
Accepted: 03-12-2023

Aishwarya Patil
Ph.D. Scholar, Department of Agricultural Economics & Statistics, Post Graduate Institute, Dr. PDKV, Akola, Maharashtra, India

Nishant Shende
Head, Department of Agricultural Economics & Statistics, Post Graduate Institute, Dr. PDKV, Akola, Maharashtra, India

Corresponding Author:
Aishwarya Patil
Ph.D. Scholar, Department of Agricultural Economics & Statistics, Post Graduate Institute, Dr. PDKV, Akola, Maharashtra, India

Impact of climate change on productivity of soybean in Akola district of Maharashtra

Aishwarya Patil and Nishant Shende

Abstract
The present study has been conducted to study the impact of climate change on productivity of soybean in Akola district. Time series data ranging from 1901 to 2020 on area, production, productivity of soybean has been taken from government publications, websites. The data of selected climatic factors such as rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, wind speed, bright sunshine hours, evaporation has been collected from Department of Agronomy, Dr. PDKV, Akola. The Shapiro-Wilk test has been used for checking normality of data. Karl Person's Correlation Coefficient and Spearman's Rank Correlation has been used to examine the relationship between area, production, productivity and climatic factors for soybean crops. Furthermore, Multiple Linear Regression Technique has been used to study the impact of climate change on productivity of soybean. Mann-Kendall test and Sen's Slope Estimator has been used to identify the trends in selected climatic factors with their magnitude. The results revealed that, Productivity of soybean data follows normal distribution where area and production does not follows normal distribution. Area of soybean is strongly positively correlated with production of soybean which is significant both at 5 per cent and 1 per cent level of significance. For soybean crop, minimum temperature does not follow the normal distribution. Productivity of soybean is positively correlated with rainfall which is significant at 5 per cent level of significance. The results of multiple regression indicates that 33 per cent of variation in productivity of soybean is due to climatic factors. The result of trend analysis indicates that for soybean crop there is negative (decreasing) trend for wind speed and bright sunshine hours.

Keywords: Climate change, productivity, Shapiro-wilk test, Mann-kendall test, Sen's slope, soybean

1. Introduction
Climate change is one of the most serious environmental issue of the twenty-first century. Changes are noticed in all sectors of life including agriculture. Particularly, Indian agriculture is hardly affected due to the climate change. Climate change is nothing but the statistically significant variation in either the mean state of climate or in its variability, which is remaining for longer period (Anonymous, 2007) [1]. This variation may be due to natural internal processes occurred within climatic system or to variation in natural or anthropogenic external forcing. The rate of warming temperature in 21st century to be 0.8 ℃ and 4.4 ℃ at various stabilized levels of CO_2 in atmosphere and which will be 3℃ by the end of this century (Anonymous, 2006) [2]. This major change in climate is mainly due to increased carbon dioxide emission into the atmosphere & human activities. So, the years 2016 & 2020 are declared as the warmest year on record (Anonymous, 2021) [3]. Climate change has it's impact on food production are not limited to crops. It will affect food production and food security directly or indirectly by affecting agricultural production systems. The impact of climate change on agricultural production is important at local, regional, national as well as global scales. This paper aims to work out the normality of area, production, productivity and climatic factors soybean crop and their correlation, impact of climatic factors on productivity of soybean and assessing trends in climatic factors during soybean growing period for Akola district.

2. Materials and Methods
The nature of the present study is mainly based on secondary data. In order to attain the objectives of the study, relevant secondary data for a period of 30 years, i.e., from 1991-2020 have been taken for analysis.

2.1. Collection of Data

The study was based on secondary data mainly collected from various government reports, publications and related websites. Area, production and productivity of soybean for Akola district of Maharashtra state with 30 years data ranging from 1991-2020 was utilized for this study. While for climatic data, it was collected from Department of Agronomy, Dr. PDKV, Akola.

2.2. Analytical tools

For statistical analysis "IBM SPSS v.20" and "XLSTAT" software were used.

2.2.1. Shapiro-Wlik Test

There are different normality test but for our sample data we use Shapiro-Wilk test test was mostly used for sample size of less than 50. Given an ordered random sample, $y_1 < y_2 < \ldots < y_n$, the original Shapiro-Wilk test statistic is defined as,

$$W = \frac{(\sum_{i=1}^{n} a_i y_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

Where y_i is the i[th] order statistic,
$\bar{y}$ is the sample mean,

$$a_i = (a_1, \ldots, a_n) = \frac{m^T V^{-1}}{(m^T V^{-1} V^{-1} m)^{1/2}}$$

And $m = (m_1, \ldots m_n)^T$ are the expected values of the order statistics of independent and identically distributed random variables sampled from the standard normal distribution and V is the covariance matrix of those order statistics.

2.2.2. Correlation between area, production, productivity and climatic factors

Karl Pearson's Correlation Coefficient (1895) is used when both variables being studied are normally distributed.

$$r_{xy} = \frac{\left|\sum xy - \frac{\sum x \sum y}{n}\right|}{\sqrt{\left(\sum x^2 - \frac{(\sum x^2)}{n}\right)\left(\sum y^2 - \frac{(\sum y^2)}{n}\right)}}$$

Where,
r_{xy} = Correlation Coefficient
x = Climatic factors
y = Productivity
n = Number of years

2.2.3. Multiple Linear Regression

By using multiple linear regression the impact of climate change on productivity of selected crops were analyzed.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8$$

Where,
Y = Productivity kg/ha
a = Intercept
X_1 = Rainfall (mm)
X_2 = Maximum Temperature (°C)
X_3 = Minimum Temperature (°C)
X_4 = Morning Relative Humidity (%)
X_5 = Evening Relative Humidity (%)
X_6 = Wind Speed (Km/hr)
X_7 = Bright sunshine hours (hrs)
X_8 = Evaporation (mm)

2.2.4. Trend Analysis

The Mann-Kendall test is a non-parametric test used for identifying trends in climatological and hydrological time series data. According to this test, the null hypothesis H_0 assumes that there is no trend and this is tested against the alternative hypothesis H_1 which assumes that there is a trend. The general test Mann-Kendall test has test statistics S defined as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (X_j - X_i)$$

Where X_j is the sequential data series, n is the length of the data set and

$$Sgn\ (y) = 1\ if\ (y > 0)\ 0\ if\ (y = 0)$$

$$-1\ if\ (y < 0)$$

Result of Mann-Kendall test are to be normally distributed for $(n \geq 8)$ with mean and variance described as:

$$V(S) = \frac{n(n-1)(2n+5) + \sum t_i(t_i - 1)(2t_i + 5)}{18}$$

Where t_i is the number of ties present with i as extent. The standardized Z statistics is computed by

$$Z = \frac{S-1}{\sqrt{var(S)}}\ S > 0$$

$$= 0\ S = 0$$

$$= \frac{S+1}{\sqrt{var(S)}}\ S < 0$$

The standard statistic Z follows the standard normal distribution with zero mean and unit variance.

2.2.5. Sen's Slope Estimator Test:

The magnitude of a trend in a time series can be determined using a non-parametric method known as Sen's Estimator (Sen, 1968). To estimate the true slope of an existing trend such as amount of change per year, Sen's non parametric method is used. Sen's method can be used in cases where the trend can be assumed to be linear such as

$$f(t) = Q_t + B$$

Here, Q is the slope and B is a constant. Slopes of data value pairs are calculated as,

$$Q_i = \frac{x_j - x_k}{j - k}$$

Here x_j and x_k are the data values in years j and k, $j > k$. If there is N values of x_j in time series then the Sen's estimator is

$$Q = Q_{[N+1/_2]} \ if \ N \ is \ odd$$

$$Q = \frac{1}{2}\left(Q_{[N/_2]} + Q_{[N+1/_2]}\right) \ if \ N \ is \ even$$

The positive value of Q_i indicates an upward or increasing trend and a negative value gives a downward or decreasing trend in the time series.

3. Results and Discussion

3.1. Shapiro-Wilk Test

Normality test is carried out for checking whether the area, production, productivity of soybean including selected climatic factors are normally distributed or not. For this the Shapiro-Wilk test is used.

Table 1: Testing Normality of Area, Production and Productivity of Soybean

Parameters	Statistic (W)	P Value
Area	0.86	0.00
Production	0.86	0.00
Productivity	0.98	0.80

From above table, it is revealed that the p-value for area, production and productivity are 0.001, 0.001 and 0.801 respectively. From this it is concluded that as p- values of area and production are less than that significance level i.e. 0.05, which means the data does not follows normal distribution. Whereas, p- value of productivity is more than level of significance which concluded that the data follows normal distribution.

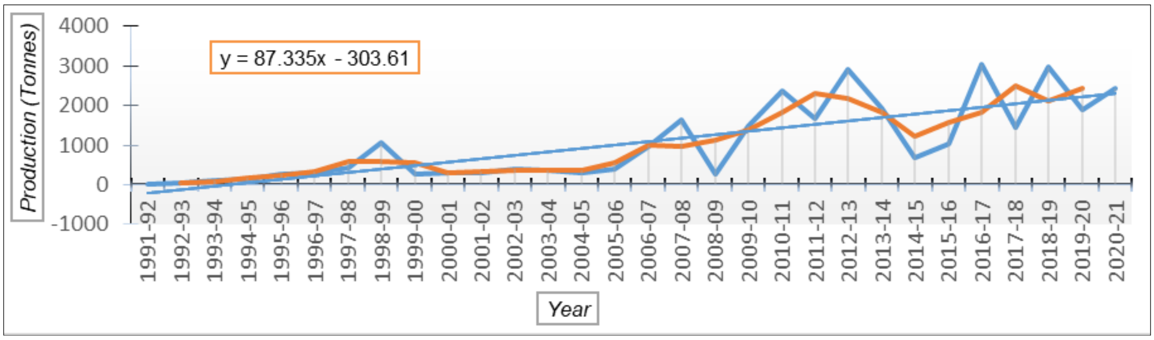

Fig 1: showing the time series analysis for the area (ha) under soybean in Akola district by using three years moving average method. From fig. it is clearly observed that area under soybean in Akola district is rising over period of time.

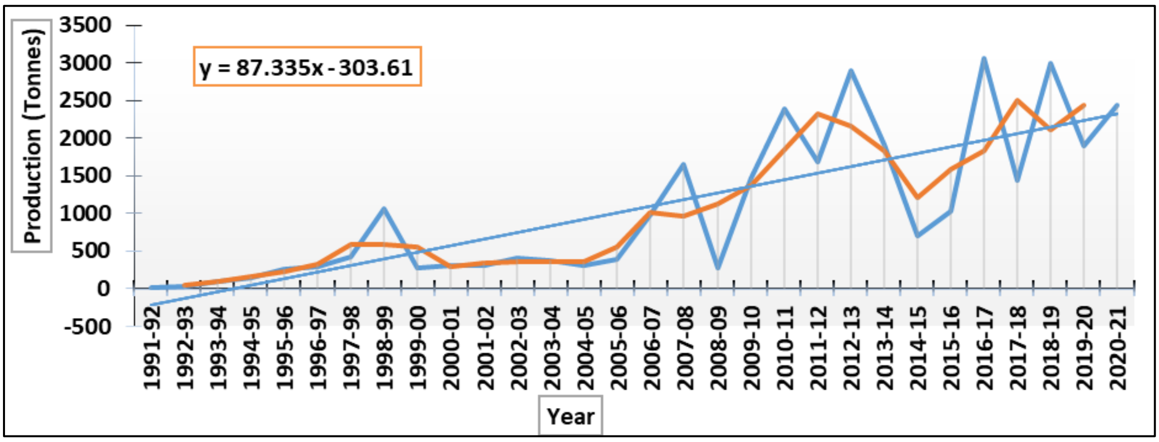

Fig 2: Showing the time series analysis for the production (Tonnes) under soybean in Akola district by using three years moving average method. It is observed that productivity of soybean in Akola district is increasing over period of time.

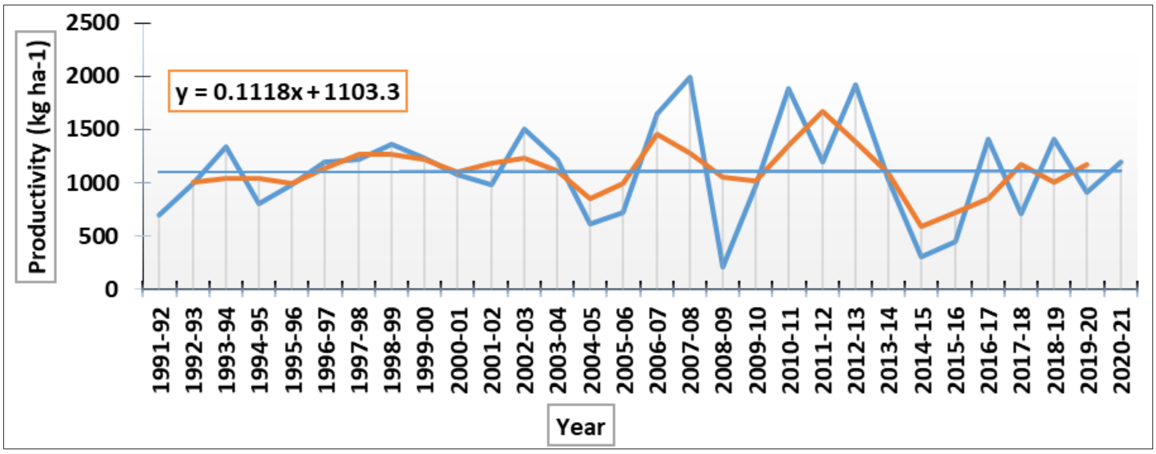

Fig 3: showing the time series analysis for the productivity (kg ha^{-1}) under soybean in Akola district by using three years moving average method. From fig. it is clearly observed that productivity of soybean in Akola district is constant growing over period of time.

Table 2: Testing Normality of Productivity of Soybean and Climatic Factors

Parameters	Statistic (W)	P values
Productivity	0.979	0.801
Rainfall (mm)	0.962	0.343
T_{max} (℃)	0.981	0.843
T_{min} (℃)	0.865	0.001
RH-I (%)	0.981	0.851
RH-II (%)	0.982	0.870
Wind speed (km/hr)	0.948	0.151
Bright Sunshine hours (hrs)	0.963	0.359
Evaporation (mm)	0.969	0.502

From above table, it is revealed that the p-value of Minimum temperature is less than the level of significance i.e. 0.05, so the data does not follow normal distribution. Whereas, p values of productivity, rainfall, maximum temperature, minimum temperature, wind speed, morning relative humidity, evening relative humidity, bright sunshine hours, evaporation are more than level of significance i.e. 0.05 which indicates that these data follows normal distribution.

3.2. Karl Pearson's Correlation and Spearman Rank Correlation

The result concluded that, area of soybean is highly positively correlated with production of soybean which is significant at both 5 per cent and 1 per cent level of significance. Also, there is positive correlation between production and productivity of soybean which is significant at 5 per cent level of significance. Whereas, productivity of soybean is negatively correlated with area of soybean and the relationship is not significant.

Table 3: Testing Correlation between Area, Production and Productivity of Soybean (N = 30)

Spearman Rank correlation		Area	Production	Productivity
Area	Pearson Correlation	1.00	0.82**	-0.06
	Sig. (2-tailed)	.	0.00	0.76
Production	Pearson Correlation	0.82**	1.00	0.41*
	Sig. (2-tailed)	0.00	.	0.03
Productivity	Pearson Correlation	-0.06	0.41*	1.00
	Sig. (2-tailed)	0.76	0.03	.

(Note: **, * indicates significance at 1% and 5% level of significance)

Table 4: Testing Correlation between Productivity of Soybean and Climatic Factors (N = 30)

Parameters		Productivity	Rainfall	T_{max}	T_{min}	RH-I	RH-II	Wind speed	BSH	Evaporation
Productivity	Pearson Correlation	1	0.43*	-0.32	0.13	0.24	0.33	-0.18	-0.15	-0.38*
	Sig. (2-tailed)		0.02	0.08	0.48	0.21	0.08	0.33	0.43	0.03
Rainfall	Pearson Correlation	0.43*	1	-0.42*	-0.21	0.54**	0.59**	-0.36*	-0.18	-0.55**
	Sig. (2-tailed)	0.02		0.02	0.28	0.00	0.00	0.05	0.35	0.00
T_{max}	Pearson Correlation	-0.32	-0.42*	1	0.21	-0.54**	-0.80**	0.20	0.70**	0.84**
	Sig. (2-tailed)	0.08	0.02		0.27	0.00	0.00	0.30	0.00	0.00
T_{max}	Pearson Correlation	0.13	-0.21	0.21	1	-0.03	-0.23	-0.08	-0.06	0.34
	Sig. (2-tailed)	0.48	0.28	0.27		0.89	0.22	0.66	0.76	0.07
RH-I	Pearson Correlation	0.24	0.54**	-0.54**	-0.03	1	0.72**	-0.48**	-0.42*	-0.56**
	Sig. (2-tailed)	0.21	0.00	0.00	0.89		0.00	0.00	0.02	0.00
RH-II	Pearson Correlation	0.33	0.59**	-0.80**	-0.23	0.72**	1	-0.12	-0.45*	-0.77**
	Sig. (2-tailed)	0.08	0.00	0.00	0.22	0.00		0.51	0.01	0.00
Wind speed	Pearson Correlation	-0.18	-0.36*	0.20	-0.08	-0.48**	-0.12	1	0.51**	0.19
	Sig. (2-tailed)	0.33	0.05	0.30	0.66	0.00	0.51		0.00	0.32
BSH	Pearson Correlation	-0.15	-0.18	0.70**	-0.06	-0.42*	-0.45*	0.51**	1	0.44*
	Sig. (2-tailed)	0.43	0.35	0.00	0.76	0.02	0.01	0.00		0.02
Evaporation	Pearson Correlation	-0.38*	-0.55**	0.84**	0.34	-0.56**	-0.77**	0.19	0.44*	1
	Sig. (2-tailed)	0.04	0.00	0.00	0.07	0.00	0.00	0.32	0.02	

(Note: ** & * denotes significance at 1% and 5% level of significance)

From above table, Productivity of soybean is positively correlated with rainfall, minimum temperature, morning relative humidity, evening relative humidity. Out of this relationship with rainfall is significant at 5 per cent level of significance. Also, productivity is negatively correlated with maximum temperature, wind speed, bright sunshine hours and evaporation. Out of this relationship with evaporation is significant at 5 per cent level of significance. There is positive correlation between productivity and morning relative humidity which is significant at 5 per cent level of significance.

3.3. Multiple Linear Regression

Impact of different climatic factors such as rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, wind speed, sunshine hours, evaporation on productivity of cotton and soybean was analysed by using Multiple Regression Technique.

The multiple regression equation obtained showed R^2 value equal to 0.33, this implies that about 33 per cent of variation in productivity of cotton is accounted by the climatic factors such as rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, wind speed, bright sunshine hours, evaporation at crop duration period. From above table, it is revealed that p value of model is greater than the level of significance i.e. 0.05 which indicates that the estimated multiple regression model is non-significant.

Table 5: Impact of climate change on productivity of soybean

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate	F	p value
2	0.57	0.33	0.074	426.40	1.29	0.30

Table 6: Multiple linear regression model for soybean productivity

Model	B	Std. Error	"t" Value	"p" Value
Constant	1674.15	9142.92	0.18	0.86
Rainfall (mm)	4.01	3.20	1.25	0.23
T_{max} (°C)	-93.09	277.89	-0.34	0.74
T_{min} (°C)	237.84	135.17	1.76	0.09
RH-I (%)	-38.16	48.27	-0.79	0.44
RH-II (%)	9.46	45.10	0.21	0.84
Wind speed (km/hr)	-36.87	70.28	-0.53	0.61
Bright Sunshine hours (hrs)	105.39	192.18	0.55	0.59
Evaporation (mm)	-197.89	269.48	-0.73	0.47

The resultant multiple regression equation is derived and expressed as,

$$Y = 1674.15 + 4.01X_1 - 93.09X_2 + 237.84X_3 - 38.16X_4 + 9.46X_5 - 36.87X_6 + 105.39X_7 - 197.89X_8$$

Where Y is productivity of cotton, X_1 is rainfall (mm), X_2 is maximum temperature (°C), X_3 is minimum temperature (°C), X_4 is morning relative humidity (%), X_5 is evening relative humidity (%), X_6 is wind speed (km/hr), X_7 is bright sunshine hours (hrs), X_8 is evaporation (mm). From this equation, it is observed that effect of rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, wind speed, bright sunshine hours and evaporation found non-significant effect on productivity of soybean.

3.4. Trend Analysis

Trend analysis of different climatic factors such as rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, wind speed, sunshine hours, evaporation was carried out for 30 years data by using Mann-Kendall Test and Sen's Slope Estimator Test.

Table 7: Trends in selected climatic factors for soybean in Akola district

Parameter	Kendall's tau	p-value (Two-tailed)	Sen's slope
Rainfall (mm)	0.048	0.721	0.358
T_{max} (°C)	-0.217	0.097	-0.026
T_{min} (°C)	0.196	0.134	0.017
RH-I (%)	0.144	0.276	0.080
RH-II (%)	0.019	0.900	0.017
Wind speed (km/hr)	-0.480	**0.000**	-0.157
Bright Sunshine hours (hrs)	-0.441	**0.001**	-0.060
Evaporation (mm)	-0.044	0.748	-0.005

Above table represents the magnitude of climatic factors for soybean crop obtained from the Mann-Kendall test and Sen's slope estimator. From this, it is concluded that as p value of wind speed, bright sunshine hours is less than that level of significance i.e. 0.05 which indicates that there is trend for wind speed, bright sunshine hours. Whereas the wind speed and bright sunshine hours shows negative (decreasing) trends because the Sen's slope and Kendall's tau (Z) values were negative. Other climatic factors such as rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, evaporation has p value greater than level of significance i.e. 0.05 which indicates that there is no trend present for these climatic factors.

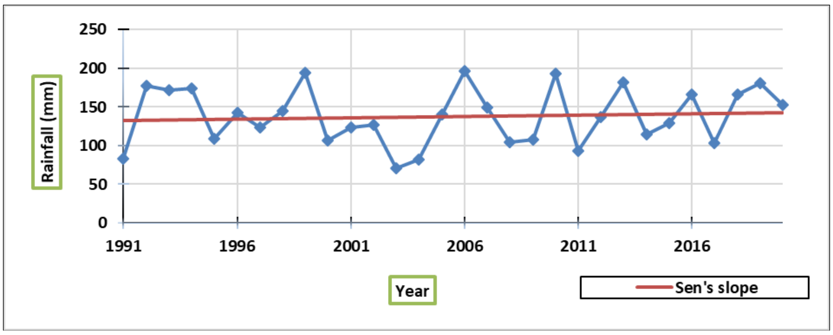

Fig 4: Showing the trend and sen's slope of rainfall for soybean. It indicates that Man-Kendall test has p- value greater than level of significance. i.e. 0.05, so as per test statistics it is concluded that rainfall for soybean does not have trend in it's time series.

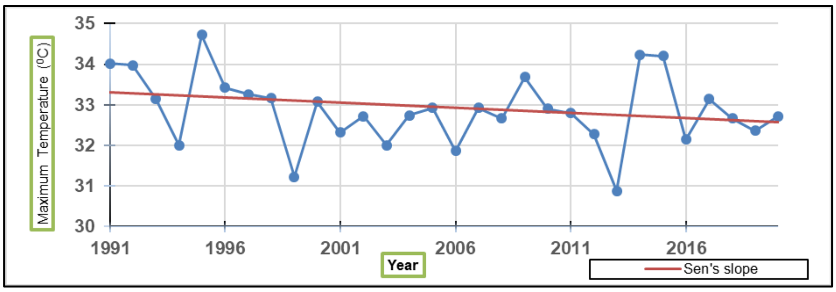

Fig 5: Showing the trend and sen's slope of maximum temperature for soybean. It indicates that Man-Kendall test has p- value greater than level of significance. i.e. 0.05, so as per test statistics it is concluded that maximum temperature for soybean does not have trend in it's time series.

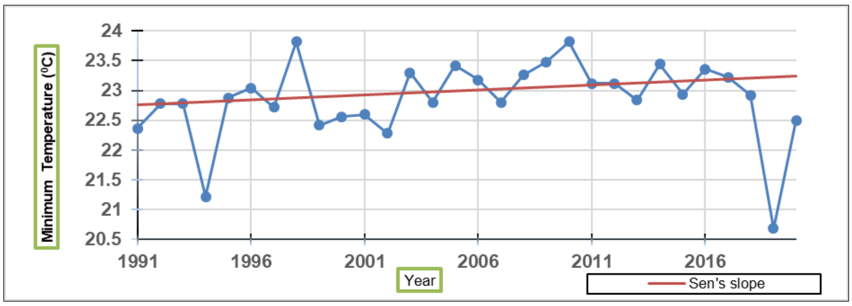

Fig 6: Showing the trend and sen's slope of minimum temperature for soybean. It indicates that Man-Kendall test has p- value greater than level of significance. i.e. 0.05, so as per test statistics it is concluded that minimum temperature for soybean does not have trend in it's time series.

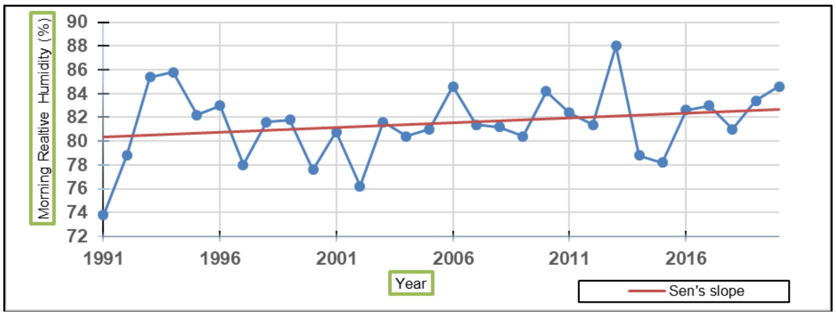

Fig 7: Showing the trend and sen's slope of morning relative humidity for soybean. It indicates that Man-Kendall test has p- value greater than level of significance. i.e. 0.05, so as per test statistics it is concluded that morning relative humidity for soybean does not have trend in it's time series.

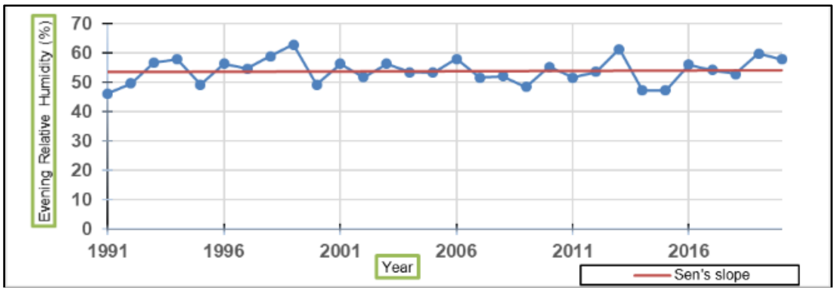

Fig 8: Showing the trend and sen's slope of evening relative humdity for soybean. It indicates that Man-Kendall test has p- value greater than level of significance. i.e. 0.05, so as per test statistics it is concluded that evening relative humidity for soybean does not have trend in it's time series.

Fig 9: Showing the trend and sen's slope of wind speed for soybean. It indicates that Man-Kendall test has p- value less than level of significance. i.e. 0.05, so as per test statistics it is concluded that wind speed for soybean have trend in it's time series and sen's slope having neagtive value which indicates that there is decreasing trend over period of time.

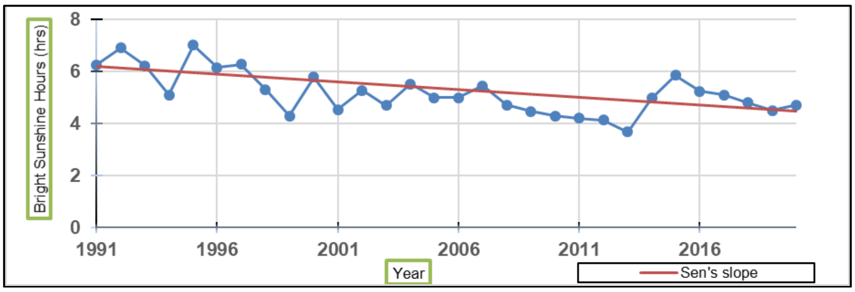

Fig 10: Showing the trend and sen's slope of bright sunshine hours for soybean. It indicates that Man-Kendall test has p- value less than level of significance. i.e. 0.05, so as per test statistics it is concluded that bright sunshine hours for soybean have trend in it's time series and sen's slope having neagtive value which indicates that there is decreasing trend over period of time.

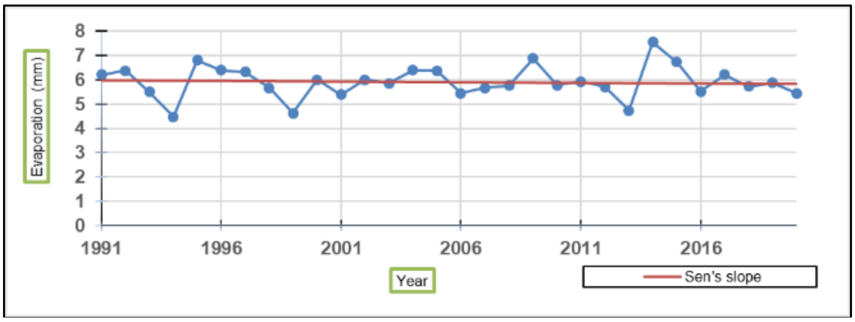

Fig 11: Showing the trend and sen's slope of evaporation for soybean. It indicates that Man-Kendall test has p- value less than level of significance. i.e. 0.05, so as per test statistics it is concluded that evaporation for soybean does not have trend in it's time series.

4. Conclusion

This study presents the impact of climatic factors on productivity of soybean in Akola district by using annual data covering the period from 1991 to 2020. The results obtained from the present study are summarized in the following conclusion. Productivity of soybean data follows normal distribution whereas production and area of soybean does not follow normal distribution. The study revealed that area of soybean is highly positively correlated with production of soybean which is significant both at 5 per cent and 1 per cent level of significance whereas production and productivity of soybean are positively correlated which is significant at 5 per cent level of significance. For soybean crop rainfall, maximum temperature, morning relative humidity, evening relative humidity, wind speed, bright sunshine hours, evaporation data follows normal distribution except minimum temperature.

The study examined that that productivity of soybean is positively correlated with rainfall which is significant at 5 per cent level of significance. Whereas, there is negative correlation between productivity and evaporation which is significant at 5 per cent level of significance. The results of multiple regression equation provides that 33 per cent of variation in productivity of soybean is due to climatic factors. The study further presents that no any climatic factor found to be significant for productivity of soybean. The result of trend analysis indicates that that there is negative (decreasing) trend for wind speed and bright sunshine hours.

5. References

1. Anonymous. Climate change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Geneva, Switzerland; c2007. p. 104.
2. Anonymous. Assessment of Climate Change over the Indian Region, A report of Ministry of Earth Sciences, Government of India; c2020.
3. Anonymous. Climate Change 2021: Summary for Policymakers. The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press; c2021.
4. Anonymous. Global Climate Change, Vital Signs of the Planet, NASA; c2021.
5. Aswad FK, Ali AY, Soyran AI. Trend analysis using Mann-Kendall and Sen's Slope Estimator test for annual and monthly rainfall for Sinjar Districts, Iraq. Journal of University of Duhok. 2020;23(2):501-508.
6. David E, Vera K, Laura S. Who suffers most from extreme weather events? Weather-related loss events in 2000-2019. Global Climate Risk Index, German watch. c2021.
7. Dendage VR, Khobragade AM, Bagade AB, Chavan KK. Development of Regression Model to Predict the Seed Cotton Yield with Meteorological Variables. Journal of Agriculture Research and Technology. 2018;43(1):089-092.
8. Deshmukh DT, Lunge HS. Impact of Global Warming on Rainfall and Cotton Lint with Vulnerability Profiles of Five Districts in Vidarbha, India. International Journal of Scientific and Technology Research. 2012, 1(11).
9. Jadhav JD, Shinde VA, Pawar PB, Patil JB, Amrutsagar VM. Climate change impact on Production, Productivity of major kharif cereals in Western Maharashtra. National seminar "Recent Trends in Plant Sciences and Agricultural Research", Contemporary Research in India, ISSN: 2231-2137; c2018.
10. Jagtap DN, Ingale PM, Dalvi AS, Bodake PS, Mahadkar UV, Burondkar MM. Annual trends of climate variables at Karjat location of Maharashtra State. Farm & Manage. 2020;5(1):1-6.
11. Kelkar SM, Kulkarni A, Koteswara Rao. Impact of climate variability and change in crop production in Maharashtra, India. Current Sciences. 2020, 118(8).
12. Kumar NS, Aggrawal PK, Swaroop R, Jain S, Saxena R, Chauhan N. Impact of climate change on crop production in Western Ghats, Coastal and North-eastern regions of India. Current Sciences. 2011, 101(3).
13. Kumar S, Upadhay SK. Impact of climate change on agricultural productivity and food security in India: A state-level analysis. Indian Journal of Agricultural Research. 2019;53(2):133-142.