# IMPACT OF WEATHER PARAMETERS ON PRODUCTIVITY OF SELECTED CROPS IN MANDYA DISTRICT- A STATISTICAL APPROACH

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**APPLIED MATHEMATICS AND COMPUTER SCIENCE**

**UNIVERSITY OF AGRICULTURAL SCIENCES**

**GKVK, BENGALURU-65**

**2014**

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**LAKSHMI, L. N.**

**PALB 2167**


*Thesis submitted to the*

***University of Agricultural Sciences, Bengaluru***

*In partial fulfillment of the requirements*

*For the award of the degree of*

*MASTER OF SCIENCE (Agriculture)*

*in*

*AGRICULTURAL STATISTICS*

BENGALURU JULY, 2014

*Affectionately dedicated to*

*My Beloved Parents*

*Nagaraju*

*And*

*Shivalingamma*

**DEPARTMENT OF AGRICULTURAL STATISTICS,
APPLIED MATHEMATICS AND COMPUTER SCIENCE
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK, BENGALURU-560065**

# CERTIFICATE

This is to certify that the thesis entitled **"IMPACT OF WEATHER PARAMETERS ON PRODUCTIVITY OF SELECTED CROPS IN MANDYA DISTRICT- A STATISTICAL APPROACH"** submitted by **Ms. LAKSHMI, L. N., ID No. PALB 2167,** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in **AGRICULTURAL STATISTICS** to the University of Agricultural Sciences, Bengaluru, is a record of research work carried out by her during the period of her study in this University, under my guidance and supervision and thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar titles.

Bengaluru
July, 2014

**H.S. SURENDRA**
Major Advisor

**Approved By:**

**Chairman** : **(H. S. SURENDRA)**

**Members** : 1. **(R. MUNIRAJAPPA)**

2. **(M. GOPINATH RAO)**

3. **(M. B. RAJEGOWGA)**

4. **(S. B. YOGANANDA)**

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July, 2014

**IMPACT OF WEATHER PARAMETERS ON PRODUCTIVITY OF SELECTED CROPS IN MANDYA DISTRICT- A STATISTICAL APPROACH**

**LAKSHMI, L. N.**

## ABSTRACT

The present study attempts to know the trend of selected weather parameters and to analyse the impact of weather parameters on productivity of ragi and sugarcane in Mandya district. The secondary data of weather parameters for the study was obtained from ZARS, V. C. Farm, Mandya for the period from 1986 to 2010. Further, the available data of crop productivity was obtained for the period from 1991-2010 (25 years). The parameters consider viz., maximum temperature, minimum temperature, relative humidity, cloudiness, wind speed, sun shine hour, rainfall and ragi and sugarcane yield for the study.

The trend analysis revealed that the maximum temperature showed a positive significant trend whereas relative humidity and rainfall showed a positive non significant trend over a period of time for most of the months. The cloudiness and sun shine hour showing a negative significant trend whereas minimum temperature and wind speed shown a negative non significant trend during study period for most of the months.

The correlation analysis indicated that the productivity of ragi and sugarcane was positively correlated with average minimum temperature, wind speed and rainfall, however negatively correlated with maximum temperature and relative humidity.

The sun shine hour contribution was higher (75.97%) towards the productivity of ragi, followed by wind speed (27.33%), cloudiness (14.67%), and rainfall (7.76%). The lowest contribution was minimum temperature (0.35%) and relative humidity (0.87%). Whereas productivity of sugarcane the maximum temperature contribution was higher (23.42%), followed by relative humidity (15.15%), minimum temperature (13.33%). The lowest contribution was sun shine hour (0.75%), followed by cloudiness (1.05%) and wind speed (1.22%).

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Major Advisor

# ಆಯ್ದ ಬೆಳೆಗಳ ಮೇಲೆ ಮಂಡ್ಯ ಜಿಲ್ಲೆಯ ಹವಮಾನದ ಮಾನದಂಡಗಳ ಪರಿಣಾಮಗಳು

ಲಕ್ಷ್ಮಿ, ಎಲ್ ಎನ್

## ಪ್ರಬಂಧ ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಲ್ಲಿ, ಮಂಡ್ಯ ಜಿಲ್ಲೆಯಲ್ಲಿನ ಹವಮಾನದ ಮಾನದಂಡಗಳ ಪ್ರವೃತ್ತಿ ಹಾಗೂ ರಾಗಿ ಮತ್ತು ಕಬ್ಬು ಬೆಳೆಗಳ ಉತ್ಪಾದಕ ಶಕ್ತಿಯ ಮೇಲೆ ಹವಮಾನ ಮಾನದಂಡಗಳ ಪರಿಣಾಮವನ್ನು ತಿಳಿಯಲು ವಿಶ್ಲೇಷಣೆ ಮಾಡಲಾಗಿತ್ತು. ಈ ಅಧ್ಯಾಯನಕ್ಕಾಗಿ ೧೯೮೬ ರಿಂದ ೨೦೧೦ ರ ವರೆಗೆ ಹವಮಾನದ ಮಾನದಂಡಗಳ ದ್ವಿತೀಯಕ ದತ್ತಾಂಶವನ್ನು ಜಡ್.ಎ.ಆರ್.ಆಸ್, ವಿ. ಸಿ. ಫ಼ಾರ್ಮ, ಮಂಡ್ಯದಲ್ಲಿ ಪಡೆಯಲಾಗಿತ್ತು. ಇದಲ್ಲದೆ, ಲಭ್ಯವಿರುವ ಬೆಳೆ ಉತ್ಪಾದಕತೆಯ ಮಾಹಿತಿಯನ್ನು ೧೯೯೧ ರಿಂದ ೨೦೧೦ ರ ವರೆಗೆ (೨೫ ವರ್ಷ) ಪಡೆಯಲಾಗಿತ್ತು. ಈ ಅಧ್ಯಾಯನಕ್ಕಾಗಿ ನಿಯತಾಂಕಗಳಾದ ಗರಿಷ್ಠ ತಾಪಮಾನ, ಕನಿಷ್ಠ ತಾಪಮಾನ, ಆರ್ದ್ರತೆ, ಮೋಡ ಕವಿದ ವಾತಾವರಣ, ಗಾಳಿಯ ವೇಗ, ಸೂರ್ಯನ ಹೊಳಪಿನ ಅವಧಿ, ಮಳೆ ಹಾಗೂ ರಾಗಿ ಮತ್ತು ಕಬ್ಬಿನ ಇಳುವರಿ ಪರಿಗಣಿಸಲಾಗಿತ್ತು.

ಪ್ರವೃತ್ತಿ ವಿಶ್ಲೇಶಣೆಯಿಂದ ತಿಳಿಯಲಾದ ಅಂಶವೇನೆಂದರೆ, ಗರಿಷ್ಠ ತಾಪಮಾನವು ಧನಾತ್ಮಕ ಗಮನಾರ್ಹ ಪ್ರವೃತ್ತಿ ತೋರಿತು. ಆದರೆ ಆರ್ದ್ರತೆ ಮತ್ತು ಮಳೆಯು ತಿಂಗಳ ಹೆಚ್ಚಿನ ಅಧ್ಯಾಯನದಲ್ಲಿ ಧನಾತ್ಮಕ ಗಮನಾರ್ಹವಲ್ಲದ ಪ್ರವೃತ್ತಿ ತೋರಿತು. ಮೋಡ ಕವಿದ ವಾತಾವರಣ ಮತ್ತು ಸೂರ್ಯನ ಹೊಳಪು ತಿಂಗಳ ಹೆಚ್ಚಿನ ಅಧ್ಯಾಯನದಲ್ಲಿ ನರಾತ್ಮಕ ಗಮನಾರ್ಹ ಪ್ರವೃತ್ತಿ ತೋರಿತು ಆದರೆ ಕನಿಷ್ಠ ತಾಪಮಾನ ಮತ್ತು ಗಾಳಿಯ ವೇಗ ನರಾತ್ಮಕ ಗಮನಾರ್ಹವಲ್ಲದ ಪ್ರವೃತ್ತಿ ತೋರಿತು.

ರಾಗಿ ಮತ್ತು ಕಬ್ಬಿನ ಉತ್ಪಾದನೆಯು ಸರಾಸರಿ ಕನಿಷ್ಠ ತಾಪಮಾನ, ಗಾಳಿಯ ವೇಗ ಮತ್ತು ಮಳೆಯ ಜೊತೆ ಧನಾತ್ಮಕ ಸಂಬಂದವನ್ನು ಹೊಂದಿದ್ದು ಹಾಗೆಯೇ ಗರಿಷ್ಠ ತಾಪಮಾನ ಮತ್ತು ಆರ್ದ್ರತೆಯ ಜೊತೆ ನರಾತ್ಮಕ ಸಂಬಂದವನ್ನು ಹೊಂದಿದ್ದು, ಇದನ್ನು ಪರಸ್ಪರ ವಿಶ್ಲೇಷಣೆ ಯಿಂದ ತಿಳಿಯಲಾಯಿತು.

ರಾಗಿ ಉತ್ಪಾದನೆಗೆ ಸೂರ್ಯನ ಹೊಳಪಿನ ಅವಧಿಯ (೬೫.೯೬%) ಕೊಡುಗೆ ಅಧಿಕವಾಗಿದ್ದು, ತದನಂತರ ಗಾಳಿಯ ವೇಗ (೨೬.೩೩%), ಮೋಡ ಕವಿದ ವಾತಾವರಣ (೧೪.೯೬%) ಮತ್ತು ಮಳೆ (೬.೬೯%) ಹಾಗೂ ಕನಿಷ್ಠ ತಾಪಮಾನ (೦.೩೫%) ಮತ್ತು ಆರ್ದ್ರತೆಯು (೦.೮೬%) ಕಡಿಮೆ ಕೊಡುಗೆಯನ್ನು ನೀಡಿತ್ತು. ಹಾಗೆಯೇ ಕಬ್ಬಿನ ಉತ್ಪಾದನೆಗೆ ಗರಿಷ್ಠ ತಾಪಮಾನದ (೨೩.೪೨%) ಕೊಡುಗೆ ಅಧಿಕವಾಗಿದ್ದು, ತದನಂತರ ಆರ್ದ್ರತೆ (೧೫.೧೫%) ಮತ್ತು ಕನಿಷ್ಠ ತಾಪಮಾನ (೧೩.೩೩%) ಹಾಗೂ ಸೂರ್ಯನ ಹೊಳಪಿನ ಅವಧಿ (೦.೬೫%) ಕಡಿಮೆ ಕೊಡುಗೆಯನ್ನು ನೀಡಿದ್ದು ತದನಂತರ ಮೋಡ ಕವಿದ ವಾತಾವರಣ (೧.೦೫%) ಮತ್ತು ಗಾಳಿಯ ವೇಗ (೧.೨೨%).

ಕೃಷಿ ಸಂಖ್ಯಾಶಾಸ್ತ್ರ ವಿಭಾಗ,
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(ಪ್ರಮುಖ ಸಲಹೆಗಾರ)

# Trend Analysis of Long Term Weather Parameters in Mandya District


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## INTRODUCTION

- The agro-meteorological information is useful for the solution in agricultural problems. Without studying the trends, adoption of farming system to an region might be unsuccessful with the future climatic conditions.
- Investigations of regional and global climatic changes and variability and their impacts on the society have received considerable attention in recent years.
- Mandya District is one of the most agriculturally prosperous districts in Karnataka and the district and height above mean sea level is 695mt.
- Majority of Geographical area of Mandya district is covered by Cauvery basin and agriculture in the district is classified under agro-climatic zone 6 (Southern dry Zone).
- Weather components namely rainfall, temperature, relative humidity, sunshine hours, cloudness, wind speed evopotranspiration, etc., plays a very important and significant role in cropping pattern and agricultural crop production.
- It has a profound influence on crop growth, development, yields, the incidence of pests and diseases, water needs and on desired fertilizer requirements.

## OBJECTIVE

- To study the trend in the weather parameters over study period.

## METTHODOLOGY

**Study area**

- For this study Mandya District has been selected.

**Data base**

- The secondary data on the selected weather parameters were collected from the Zonal Agricultural Research Station, V. C. Farm, Mandya.

**Weather Parameters:**

The average monthly data were collected over 25 years from 1986-2010 for the following weather parameters.

$X_1$: Max. temperature (Temp. Max $^0$C)
$X_2$: Min. temperature ( Temp. Min $^0$C)
$X_3$: Rainfall ( RF mm)
$X_4$: Relative Humidity (RH %)
$X_5$: Cloudness (Oktas)
$X_6$: Wind speed (WS Km/hr)
$X_7$: Sun Shine Hours (SSH hr)

**Analytical tools and techniques**

- Descriptive statistics.
- Fitted appropriate regression equations such as Exponential and Logarithmic models.

## RESULTS

**Mean Temperature, Relative Humidity, cloudness, Wind speed, Sun Shine Hour, Rainfall for the Period January- December during 1986-2010.**

| Period | Max. Temp ($^0$C) | Min. Temp ($^0$C) | RH (%) | Cloudness (oktas) | Wind speed (Km/hr) | SSH (hr) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| Jan | 29.22 | 14.19 | 86.69 | 1.56 | 5.21 | 7.36 | 1.00 |
| Feb | 31.23 | 16.10 | 86.94 | 1.52 | 4.19 | 8.27 | 3.76 |
| Mar | 34.03 | 18.43 | 83.92 | 1.22 | 4.62 | 8.32 | 12.30 |
| Apr | 32.15 | 20.64 | 82.72 | 1.41 | 4.74 | 7.90 | 52.12 |
| May | 33.44 | 20.71 | 85.03 | 1.71 | 4.59 | 7.94 | 72.80 |
| Jun | 32.57 | 20.21 | 86.76 | 2.09 | 5.73 | 6.01 | 66.40 |
| Jul | 29.25 | 19.88 | 87.52 | 2.08 | 6.67 | 5.30 | 56.00 |
| Aug | 28.84 | 19.81 | 87.84 | 1.86 | 5.37 | 4.93 | 77.00 |
| Sep | 29.42 | 19.74 | 87.86 | 1.98 | 4.70 | 5.28 | 120.40 |
| Oct | 29.41 | 19.32 | 89.64 | 2.17 | 4.62 | 5.23 | 160.00 |
| Nov | 28.94 | 17.74 | 88.24 | 1.75 | 4.81 | 5.72 | 48.20 |
| Dec | 28.45 | 15.03 | 87.26 | 1.56 | 5.55 | 6.58 | 19.04 |

**Regression equation fitted for Jan-Dec using Logarithmic and Exponential model.**

| Period | | Temp. Max | | Temp. Min | | RH | | Cloudiness | | WS | | SSH | | RF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Exp. | Log. | Exp. | Log. | Exp. | Log. | Exp. | Log. | Exp. | Log. | Exp. | Log. | Log. |
| Jan | b | 0.003** | 0.671* | 0.003 | 0.402 | 0.001 | 0.677 | -0.03** | -0.41** | 0.002 | -0.002 | -0.017** | -1.303** | 0.227 |
| | $R^2$ | 0.370 | 0.222 | 0.109 | 0.081 | 0.040 | 0.033 | 0.367 | 0.359 | 0.001 | 0.002 | 0.348 | 0.478 | 0.003 |
| Feb | b | 0.002* | 0.390 | 0.001 | -0.041 | 0.001 | 0.890 | -0.04** | -0.42** | 0.002 | 0.161 | -0.016** | -1.394** | 2.827 |
| | $R^2$ | 0.181 | 0.171 | 0.005 | 0.001 | 0.047 | 0.035 | 0.423 | 0.303 | 0.001 | 0.004 | 0.331 | 0.476 | 0.040 |
| Mar | b | 0.000 | 0.320 | 0.001 | -0.19 | 0.001 | 0.369 | - | -0.39* | -0.005 | -0.388 | -0.014* | -1.146** | 11.91 |
| | $R^2$ | 0.102 | 0.113 | 0.016 | 0.019 | 0.033 | 0.005 | | 0.221 | 0.010 | 0.024 | 0.226 | 0.337 | 0.100 |
| Apr | b | 0.009** | 2.34** | 0.002 | 0.289 | 0.002 | 1.110 | -0.03** | -0.47** | 0.004 | 0.261 | -0.017** | -1.334** | 19.91 |
| | $R^2$ | 0.695 | 0.537 | 0.207* | 0.089 | 0.112 | 0.044 | 0.460 | 0.507 | 0.005 | 0.011 | 0.319 | 0.436 | 0.120 |
| May | b | 0.000 | 0.010 | 0.001 | 0.194 | 0.001 | 0.864 | -0.03** | -0.64** | 0.004 | 0.057 | -0.016** | -1.199** | 25.31 |
| | $R^2$ | 0.115 | 0.121 | 0.095 | 0.031 | 0.074 | 0.038 | 0.440 | 0.539 | 0.008 | 0.001 | 0.342 | 0.447 | 0.123 |
| Jun | b | -0.00** | -1.97** | 0.001 | 0.104 | 0.000 | -0.21 | - | -0.74** | 0.002 | 0.271 | -0.03** | -1.777** | -7.54 |
| | $R^2$ | 0.434 | 0.446 | 0.031 | 0.009 | 0.004 | 0.002 | | 0.575 | 0.003 | 0.018 | 0.673 | 0.748 | 0.014 |
| Jul | b | 0.002** | 0.270 | 0.001* | 0.237 | 0.002 | -0.19 | -0.04** | -0.74** | -0.013 | -0.851 | -0.019** | -1.242 | 13.57 |
| | $R^2$ | 0.237 | 0.172 | 0.206 | 0.107 | 0.005 | 0.003 | 0.518 | 0.529 | 0.128 | 0.159* | 0.278 | 0.489 | 0.056 |
| Aug | b | 0.003** | 0.560* | 0.001 | 0.218 | 0.002 | 1.467 | -0.03** | -0.45** | 0.004 | -0.046 | -0.039** | -1.924** | 8.532 |
| | $R^2$ | 0.447 | 0.248 | 0.116 | 0.073 | 0.169* | 0.124 | 0.666 | 0.534 | 0.006 | 0.001 | 0.760 | 0.820 | 0.012 |
| Sep | b | 0.002** | 0.310 | 0.001 | 0.142 | 0.001 | -0.71 | -0.04** | -0.82** | -0.007 | -0.369 | -0.029** | -1.491** | -27.5 |
| | $R^2$ | 0.317 | 0.114 | 0.132 | 0.053 | 0.003 | 0.023 | 0.552 | 0.521 | 0.061 | 0.089 | 0.353 | 0.425 | 0.059 |
| Oct | b | 0.002** | 0.460 | 0.002 | -0.05 | 0.000 | 0.118 | -0.05** | -0.78** | 0.002 | -0.271 | -0.031** | -1.749** | 16.00 |
| | $R^2$ | 0.348 | 0.120 | 0.001 | 0.004 | 0.047 | 0.003 | 0.732 | 0.474 | 0.002 | 0.043 | 0.408 | 0.595 | 0.013 |
| Nov | b | 0.004** | 0.830** | -0.00 | -0.12 | 0.000 | 0.388 | -0.03** | -0.56** | 0.005 | -0.406 | -0.027** | -1.748** | 4.893 |
| | $R^2$ | 0.587 | 0.320 | 0.015 | 0.006 | 0.028 | 0.025 | 0.455 | 0.432 | 0.003 | 0.018 | 0.333 | 0.500 | 0.004 |
| Dec | b | 0.004** | 0.870** | -0.00 | -0.48 | 0.001 | 0.624 | - | -0.67** | -0.006 | -0.335 | -0.02** | -1.49** | 1.430 |
| | | 0.610 | 0.360 | 0.130 | 0.194 | 0.059 | 0.021 | | 0.762 | 0.010 | 0.019 | 0.360 | 0.438 | 0.001 |

** Significant at 1% level * Significant at 5% level

## DISCUSSION

❖Increase in temperature from Jan-May and declined in rest of the periods. More uniformity noticed with respect to Relative Humidity (RH), optimum cloudness observed during Jun-July. wind speed was found to be more in the month of July and SSH established more in summer season and it has extended to may. Result evident that rainfall noticed highest during Sep-Oct.

❖ Exponential model was found more appropriate in establishing the trend for temperature, relative humidity and cloudiness and Logarithmic model for wind speed, sun shine hour and rainfall. The results are in conformity with the existence of available records.

❖Maximum temperature, cloudiness, SSH showing a significant trend over a period of time for most of the months, however minimum temperature, RH, WS and rainfall showing a non significant trend over a period of time for most of the months.

## SUMMARY

The mean observed for all the parameters under study found most uniformly distributed during the period of 25 years under study. Logarithmic model observed to be most feasible method in measuring the trend for rainfall, wind speed and Sun shine Hour and exponential model for temperature, relative humidity, cloudiness.

## ADVISORY COMMITTEE

Chair person: Mr .H.S Surendra

Members:

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# I. INTRODUCTION

The agro-meteorological information is most useful for solution of agricultural problems. The adoption of farming system to an area might be unsuccessful with the future climatic conditions without studying the trends. Meteorological data sets are used in evaluation of potential aspects of crop production. Investigations of regional, global climatic changes & variability and their impacts on the society have received considerable attention in recent years.

To determine the risk involved in climate change for agriculture, it is necessary to define a set of agro meteorological parameters, derived from the classic climate parameters that are capable of indicating the consequences of climate change for crop production.

India is mainly predominantly an agriculture dependent nation and the south west monsoon plays very important role in its economy and Mandya District is one of the most agriculturally prosperous districts in Karnataka. The district is located in the south east of Karnataka State and shares its borders with the districts of Mysore, Hassan, Tumkur and Bangalore. Most of the available land is flat, interspersed with hilly region and sparsely vegetated by thorns and bushes. The district is situated at the height of 762 to 914 meters above mean sea level.

The total geographical area of the Mandya district is 4,98,244 hectares, out of which 2,48,825 hectares forms the sown area. More than half of the total land area in the district is under agricultural use. The total irrigated area found to be 1,16,901 hectares and out of which around 88,000 hectares is being irrigated by K.R.Sagar and around 16,000 by Hemavathi reservoir. The rest of the land is irrigated by other sources like tanks, wells and bore wells. With the advent of irrigation from the K.R. Sagar reservoir during 1930's, there was substantially marked transformation in cropping pattern, composition of crops, better grown yield levels, ultimately leading to better economic conditions of the people.

Agriculture is the main activity in Mandya district. It is mainly dependent on rainfall, river, well and tank irrigation. Geographically, majority of Mandya district is covered by Cauvery basin and agriculture in the district is classified under agro-climatic zone 6 (Southern dry Zone). The district is blessed with irrigation from two major reservoirs, Krishnaraj Sagar and Hemavathi. Besides these, there are number of anecut channels. Anecut is a low level barrage constructed across the river. The Cauvery basin is known for extensive system of low level barrages built during the 19th century and early parts of 20th Century. Hemavathi left bank canal is irrigating parts of K.R.Pet, Nagamangala, Pandavapura and Mandya taluk. In all, about 48 percent of the total area in the district is irrigated from all sources of irrigation.

The major crops of the district are ragi (85,467 ha), rice (79,892 ha), sugarcane (30,630 ha), pulses (horse gram and to some extent tur, cowpea, green gram, black gram, avare) and oilseeds (groundnut and sesame). In the district, the major commercial crop is sugarcane. The crop sowing periods are early kharif, late kharif and summer. The average annual rainfall is 700 mm. The district gets bimodal distribution of rainfall. Generally the first peak is during April, May and the second during September, October. The month of June is known for dry spell.

Weather components namely rainfall, temperature, relative humidity, sunshine hours, cloudiness, wind speed, evapotranspiration, etc., play a very important role in agricultural production. It has a profound influence on crop growth, development and yields; on the incidence of pests and diseases; on water needs; and on fertilizer requirements. This is due to differences in nutrient mobilization as a result of water stress, as well as the timeliness and effectiveness of preventive measures, scientific and cultural operations with different crops. Weather aberrations may cause optimal physical damage to crops and soil erosion. The quality of crop produce during movement from field to storage and transport to market depends also weather conditions which lead to economic variation.

Fluctuation in weather may affect the quality of produce during transport, and the viability and vigour of seeds and planting material during storage. Thus, there is no aspect of crop culture that is immune to the impact of weather. Weather factors contribute to optimal crop growth, development and yield component. They also play a role in the incidence and spread of pests and diseases. Susceptibility to weather induced stresses and affliction by pests and diseases varies among crops, among different varieties within the same crop, and among different growth stages within the same crop variety. Even on a climatological basis, weather factors show spatial variations in an area at a given point of time, temporal variations at a specific place, and year to year variations for a given region and time.

For cropping purposes, weather over short periods and year-to-year fluctuations at a particular place over the selected time interval need to be considered. For any given time unit, the percentage departures of extreme values from a mean or median measures, indicate the coefficient of variability or a measure of variability of the parameter. The degree of variability of a given weather parameter is greater with the shorter time. The intensity of the above variations differs among the range of weather factors. Over short periods, rainfall is the most variable of all parameters, both in time and space. In fact, for rainfall the short-period inter annual variability is large, which means that variability needs to be expressed in terms of the percentage probability of realizing a given amount of rain, or that the minimum assured rainfall amounts at a given level of probability need to be specified.

For optimal productivity at a given location, crops and cropping practices must be such that cardinal phased weather requirements match the temporal march/moment of the relevant weather components, endemic periods of pests, diseases and hazardous weather are avoided. In such strategic planning of crops and cropping practices, short-period climatic data, both routine and processed (such as initial and conditional probabilities), have a vital role to play.

Despite careful agronomic planning on a micro scale to suit experience in local-climate crops, various types of weather events exist on a year-to-year basis. The effects of weather differentials/anomalies are not spectacular. Deviations from normal weather occur with higher frequencies in almost all years, areas and seasons. The most common ones are a delay in the start of the crop season due to rainfall vagaries in the case of rainfed crops (observed in the semi-arid tropics) and temperature (observed in the tropics, temperate zones and subtropics), or persistence of end of the season rains in the case of irrigated crops. Other important phenomena are deviations from the normal features in the temporal march of various weather elements. The effects of weather events on crops build up slowly but are often wide spread enough to destabilize national agricultural production.

From the above justified facts it is evident that there is a considerable scope to study the behavior of the weather parameters. Due to this reason, the present study was designed with the following specific objectives confining to only Mandya district.

1) To study the trend in the weather parameter over the study period.
2) To study the impact of weather parameters on productivity of Ragi and Sugarcane.

**Limitations of the study**

- The study is confined to only Mandya district.
- The reliability of the estimator depends on the reliability of the data recorded which is beyond the control of researcher as it is based on secondary data.
- The study limited to only 25 years of data from 1986-2010 for trend analysis.
- The study limited to only 20 years of data from 1991-2010 to measure the impact of weather parameters on ragi and sugarcane productivity.
- The study is based on only the averaged weather parameter and yield, other parameter such as crop growth stages, dry matter, and pest disease occurrences, physiological aspects of crop, and dry spells etc. are not taken into account for the present study.
- The inferences and conclusion drawn are applicable to study area of Mandya district only.

# II. REVIEW OF LITERATURE

A review of past research considerably helps in identifying the conceptual methodological issues relevant to the present study. This would enable the researcher to collect desired information and subject them to sound reasoning and meaningful interpretation. In this chapter, studies on trend and temporal variability of weather parameters are being reviewed. Keeping in view of the objectives of the present investigation; the reviews are presented in the following headings:

2.1 Trend analysis

2.2 Impact of weather parameters on productivity of ragi and sugarcane

## 2.1 Trend analysis

Goutsidou *et al.* (1992) used 50 years data on mean temperature of the bare soil surface in Thessaloniki-Greece. The mean annual value was $20^0$C with standard deviation of $1.3^0$C. The winter is the most variable season. The analysis of these time series data showed that there were notable spell of years with values above or below the normal one. Negative trends were observed for the annual and seasonal values with the expectation of winters.

Marcelo and Kenneth (1998) analyzed spatial and temporal variability by ensuring continuous, quality data from weather station networks. It was essential to identifying suspect data and providing estimates for bad data and for data gaps. This study was conducted to quantify and contrast the spatial and temporal variability for daily weather variables for two climatic areas, eastern (sub-humid) and western (semi-arid), in the High Plains of the US. For a period of 7 years (1989 to 1995) complete data were available from 38 automated weather stations, 19 stations in each area. The daily meteorological variables studied were: maximum and minimum air temperature, relative humidity, solar radiation, wind speed and precipitation and potential evapotranspiration (ETp). The coefficient of variation ($r^2$) and standard error of estimate (SEE) were calculated by regression of daily measurements between like weather variables for various station pairings within the two climatic areas. A temporal analysis was conducted with a subset of the data and it was determined that 7 years of record are required to stabilize the variation between stations. A significant seasonal cycle was found in the SEE data for maximum and minimum temperature, solar radiation, and ETp. Results indicate that the accuracy of estimated data and associated confidence limits will vary with the time of the year.

Moonen *et al.* (2002) studied daily rainfall, evaporation and mean minimum and maximum temperature, for this he collected data since 1878 to 1999. They studied time trends in extreme rainfall and temperature events and in agro-meteorological parameters for annual and seasonal time series and this time series checked for normality with the chi-square test. They used least squares linear regression to test on increasing or decreasing trends in the meteorological and agro-meteorological parameters. They applied *t*-test and the non-parametric Kendall's '*τ*' significance test. They found that there is shift towards more extremely low rainfall events.

Pielke *et al.* (2002) evaluated long-term trends in average maximum and minimum temperatures, threshold temperatures, and growing season in eastern Colorado, USA, to explore the potential shortcomings of many climate-changes. Long-term (80 + years) mean minimum temperatures increased significantly ($P < 0.2$) in about half the stations in winter, spring, and autumn and six stations had significant decreases in the number of days per year with temperatures ≤−17.8 °C (≤0 °F).

Robeson Scott (2002) studied the relationship between mean and standard deviation of daily air temperature which estimated on a monthly time scale from 1948 to 1997. He found that for both daily maximum and daily minimum air temperature, the inverse relationship is spatially coherent for one-third to two-thirds of the contiguous USA for most months. Also the inverse relationship was fairly strong, with typical reductions in standard deviation ranging from 0.2 to 0.5°C for every 1°C increase in mean temperature.

Anjum et *al.* (2005) assessed that in Pakistan, annual mean surface temperature has a consistent rising trend since the beginning of 20th century. Rise in mean temperature of 0.6-1.0°C in arid coastal areas, arid mountains and hyper arid plains, 10-15% decrease in both winter and summer rainfall in coastal belt and hyper arid plains, 18-32% increase in rainfall in monsoon zone especially the sub-humid and humid areas is observed. There is 5% decrease in relative humidity in Balochistan, It was evident that 0.5 to 0.7% Increase in solar radiation over southern half of country. There is 3-5% decrease in cloud cover in central Pakistan with increase in sunshine hours, 3 5% increases in ETo due to 0.9°C temperature increase.

Havaldar *et al.* (2005) analyzed the southwest monsoon rainfall at Dharwad (1So 26'N, $75^0$ 0TE, 678m) during the period of 1950 to 2002 to study the trend of rainfall. The 12 year moving average technique was used for this purpose. The rainfall was nearly constant with around 500 mm in the period 1955 to 1964. Then the trend became mild oscillatory until 1982. The trend became gradual negative from the year 1983 to 1997 with the rainfall changing from 494 mm to 378 mm.

Manohar Arora *et al.* (2005) were carried out an investigation to identify trends in temperature time series of 125 stations distributed over the whole of India. The non-parametric Mann-Kendall test was applied to detect monotonic trends in annual average and seasonal temperatures. Three variables related to temperature, viz. mean, mean maximum and mean minimum, were considered for analysis on both an annual and a seasonal basis. Each year was divided into four principal seasons, viz. winter, pre-monsoon, monsoon and post-monsoon. The percentages of significant trends obtained for each parameter in the different seasons are presented. Temperature anomalies are plotted, and it is observed that annual mean temperature, mean maximum temperature and mean minimum temperature have increased at the rate of 0.42, 0.92 and 0.09°C $(100\ \text{year})^{-1}$, respectively. On a regional basis, stations of southern and western India show a rising trend of 1.06 and 0.36°C (100 year)$^{-1}$, respectively, while stations of the north Indian plains show a falling trend of –0.38°C(100 year)$^{-1}$. The seasonal mean temperature has increased by 0.94°C (100 year)-$^{1}$ for the post-monsoon season and by 1.1°C (100 year)$^{-1}$ for the winter season.

Jacob and Anil (2006) analyzed the meteorological data collected by Nimbkar Agricultural Research Institute (NARI) since 1983. The main objectives were to provide average figures and curves of Phaltan weather and to identify possible trends since 1983, especially warming. Results showed that there was indeed a clear warming trend, but it seems to be influenced by changes in the surroundings of the station (microclimate). Wind velocity and evaporation have also slightly decreased.

Prabhjyot *et al.* (2006) reported that annual and seasonal variabilities in maximum and minimum temperature and rainfall were analyzed from historical daily meteorological data for Ludhians (1970-2004). Two distinct crop growth seasons of Kharif (1 May to 31 October) and Rabi (1$^{st}$ November to 30$^{th}$ April) were characterized for seasonal trends. Both annual as well as seasonal maximum and minimum temperatures exhibited small standard deviation and coefficient of variation indicating minor variation in temperatures. The maximum temperature has remained near normal over the past three decades as the annual and kharif season maximum temperature revealed a slight decreasing trend while the Rabi season maximum temperature revealed a slight increasing trend. On the other hand, the annual Kharif and Rabi minimum temperature have increased significantly at the rate of 0.07$^{0}$C per year.

Wouter Buytaert *et al.* (2006) studied particularly in mountain environments; rainfall can be extremely variable in space and time. For many hydrological applications such as modelling, extrapolation of point rainfall measurements is necessary. Decisions about the techniques used for extrapolation, as well as the adequacy of the conclusions drawn from the final results, depend heavily on the magnitude and the nature of the uncertainty involved. They examined rainfall data from 14 rain gauges in the western mountain range of the Ecuadorian Andes. The rain gauges are located in the western part of the rio Paute basin. Spatial and temporal rainfall patterns were studied. A clear intraday pattern can be distinguished. Seasonal variation, on the other hand, is low, with a difference of about 100 mm between the driest and the wettest month on an average of about 100 mm month$^{-1}$, and only 20% dry days throughout the year. Rain gauges at a mutual distance of less than 4000 m are strongly correlated, with a Pearson correlation coefficient higher than 0.8.

Xiaodong Liu *et al.* (2006) were analyzed daily and monthly maximum and minimum surface air temperatures at 66 weather stations over the eastern and central Tibetan Plateau with elevations above 2000 m for temporal trends and during the period 1961–2003. Statistically significant warming trends were identified in various measures of the temperature regime, such as temperatures of extreme events and diurnal temperature range. We also confirmed the asymmetric pattern of greater warming trends in minimum or nighttime temperatures as compared to the daytime temperatures. The warming in regional climate caused the number of frost days to decrease significantly and the number of warm days to increase. The length of the growing season increased by approximately 17 days during the 43 years of study period.

Luo *et al.* (2008) studied on the spatial and temporal trends of precipitation in Beijiang River basin, Guangdong Province. Two nonparametric methods (Mann–Kendall and Sen’s T) were used for data analysis. The results showed that (1) downward trends of temporal distribution were mostly detected during the early flood period, especially in May, while upward trends were observed in July and the dry season; (2) downward trends of spatial distribution were mostly detected in the southern Beijiang River basin, while upward trends were observed north of this area. Our results indicated a delayed rainy season and a northward trend of the precipitation belt compared to recent years.

Murty *et al.* (2008) studied temperature trend using moving averages for 3-year, 5-year and 10-year interval for minimum and maximum temperatures of Ranichauri were calculated during 1982-2002, and they concluded that the maximum temperature had shown decreasing trend while the minimum temperature was almost stable during period of study at Hill Campus, Ranichauri.

Amit Dhorde *et al.* (2009) were investigated to find a possible link of climate change with anthropogenic activities by studying trends in different climatic parameters, particularly surface air temperature of densely populated cities. The present research aimed at quantifying the change in surface air temperature at India's four most populated cities - Delhi, Kolkata, Mumbai and Chennai. The main objective of the research was to find the impact of urbanization on temperature trends at these cities. Trends in annual and seasonal temperature series were analyzed using linear trend and Mann-Kendall test. Most of the trends showed positive change in temperature with different rates in different seasons. In some cases, the trends showed asymmetry. For example, the maximum temperature at Mumbai during winter and monsoon is significantly increasing whereas minimum temperature shows significant decrease. On the other hand remaining cities recorded significant increase in minimum temperature during winter. Further the relationship indicates a negative change in temperature with increase in population. This indicates that the effect of urbanization is more pronounced during these seasons, as far as warming is concerned. Thus, an inconsistent climatic response to urbanization is observed at these cities.

Deka *et al.* (2009) the study examines long-term changes and short-term fluctuations in ambient temperature of North East India during 1901-2003 located in part of the Eastern Himalayan region of the Brahmaputra Basin. Long-term linear trends were examined with the Mann-Kendal rank statistic and moving average method while the short-term fluctuations were studied by applying Cramer’s test. The results showed significant warming trend in annual and seasonal maximum temperature. Decrease in minimum temperature during monsoon season and its increase during post-monsoon and winter season is evident. Higher magnitudes of linear trends are observed in the maximum temperature than in the minimum temperature. Maximum temperature showed increasing tendency in the recent five decades.

Krishnakumar *et al.* (2009) were made an attempt to study temporal variation in monthly, seasonal and annual rainfall over Kerala, India, during the period from 1871 to 2005. Long term changes in rainfall determined by Man-Kendall rank statistics and linear trend. The analysis revealed significant decrease in southwest monsoon rainfall while increase in post-monsoon season over the State of Kerala which was popularly known as the “Gateway of summer monsoon”. Rainfall during winter and summer seasons showed insignificant increasing trend. Rainfall during June and July showed significant decreasing trend while increasing trend in January, February and April. Hydel power generation and water availability during summer months are the concern in the State due to rainfall decline in June and July, which were the rainiest months. At the same time, majority of plantation crops are likely to benefit due to increase in rainfall during the post-monsoon season if they were stable and prolonged.

Ogolo and Adeyemi (2009) have been observed the variations and trends of some meteorological parameters over a tropical-humid station, Ibadan (07026’N, 03° 54´E) in the southwestern part of Nigeria by using daily mean data of each of the parameters taken at the International Institute of Tropical Agriculture (I.T.T.A), Ibadan, between 1988 and 1997. The monthly series of the meteorological parameters showed an annual decreasing trend, which is not statistically significant except those of rainfall and relative humidity data series that showed an increasing trend, which is statistically significant when the Mann-Kendall (τ) and Spearman rho statistics were applied. The yearly series of the parameters show that solar radiation and evaporation rate have significant decreasing trend, while other parameters show an increasing trend that is not statistically significant. Also the yearly data series for temperature and sunshine hour appear to show similar behavior to the global warming trends.

Wong and Mok (2009) were examined past trends in the occurrences of severe weather events in Hong Kong and the Heating Degree-Days and Cooling Degree-Days relevant to engineering design. Preliminary study results showed that the extreme daily minimum and maximum temperatures at the Hong Kong Observatory Headquarters exhibited statistically significant long term rising trends. The Heating Degree-Days showed a statistically significant falling trend while the Cooling Degree-Days showed a statistically significant rising trend. Regarding rainfall, the frequency of occurrence of extreme hourly, 2-hourly and 3-hourly rainfall amounts at the Hong Kong Observatory Headquarters increased significantly. Furthermore, the extreme 10-minute mean wind speed and maximum gust at Kai Tak showed statistically significant decreasing trends. On the other hand, the trends in the extreme 4 to 24-hourly rainfall at the Hong Kong Observatory Headquarters and the extreme 10-minute mean wind speed and maximum gust at Waglan Island were not significant.

Sadiq and Qureshi (2010) showed that the average temperature of Earth’s near surface air and oceans has raised by $0.74 \pm 0.18^0$C during last 100 years. In this work the impact of the same has been explored for major urban areas of Pakistan. For this exploration long-term mean, mean-maximum and mean-minimum temperatures for the period 1961 to 2007 have been studied. The precipitation in the major cities of Pakistan, are also studied. The maximum increase in mean temperature is found to be $0.057^0$C per year (Quetta). The minimum increase is found to be 0.019$^0$C per year (in Peshawar). Both these increments are more than the global mean. An isolated discrepancy is found in mean maximum temperature of Lahore but the same can be explained in terms of heavy and prolonged monsoon rains. Moreover, precipitation in Karachi is found to be decreasing that needs to be further explored.

Rai *et al.* (2010) observed that there was a considerable difference in the monsoon and non-monsoon rainfall pattern in terms of persistence and periodicity. Approximately 20 percent rainfall time series show the presence of persistence characterized by lag-1 serial correlation. Presence of serial correlation in the time series significantly affects the Mann-Kendall's trend analysis. Original Mann-Kendall test overestimate the presence of significant trend in the series than the modified Mann-Kendall and Mann-Kendall with Pre-whitening tests. Based on the overall trend results, the original Mann-Kendall test resulted approximately 37 % more presence of significant trend than the modified Mann-Kendall test. Overall falling trend was observed in the annual rainfall, monsoon rainfall, annual rainy days, monsoon rainy days, and AI. In sixty five grid locations, spatial mean of Mann-Kendall's Z-statistics for annual rainfall and monsoon rainfall were -0.832 and -0.874, respectively. Regardless of few series having significant trend, most of the series have higher values of Z-statistic. An increasing trend with overall mean Z-statistic of +1.81 was observed in OEM which shows the gradual delay in the onset of effective monsoon in the Yamuna river basin. It may be remarked that the declining monsoon rainfall and number of monsoon rainy days along with the delay in the onset of effective monsoon (i.e. rising trend in OEM) will be the great concern while preparing the river basin management plan. It was observed that high frequency fluctuations associated with short-period cycle was dominating over the basin for annual and monsoon rainfall, OEM and AI. However, for non-monsoon rainfall low frequency fluctuations were identified.

Rao *et al.* (2010) used time series analysis of annual mean, maximum and minimum temperature of 47 stations spread across different regions in India revealed the increasing trend in maximum temperature, lowest in 20 per cent stations in north zone and highest in 75 per cent of the stations in south zone. On the other hand, increase in minimum temperature is observed in above 60 per cent.

Geethalakshmi *et al.* (2011) results showed an increasing trend for maximum, minimum temperatures and rainfall for the projected climate change over Cauvery basin of Tamil Nadu for A1B scenario using regional climate models.

Gorantiwar *et al*. (2011) analyzed the stochastic modeling of weekly reference crop evapotranspiration (ETr) in semi-arid climatic condition by using seasonal auto-regressive moving average (ARIMA) model. The weekly values of reference crop evapotranspiration (ETr) estimated by Penman monteith method for 23 years (1984-2006) were used to fit the ARIMA models of different orders. The study indicated that the ARIMA model is viable tool for forecasting the reference crop evapotranspiration. The ARIMA $(1,1,0)(1,0,1)_{52}$ satisfied the different tests of diagnostic checking resulted in the lowest value of root mean square error (RMSE) between actual ETr and forecast ETr.

Hence, ARIMA (1,1,0) $(1,0,1)_{52}$ is the best stochastic model for generation and forecasting of weekly ETr values for Solapur, Maharastra, India.

Piia Post and Olavi Karner (2011) Karner were defined statistics for describing the variability of precipitation in Estonia in terms of 15 and 30-day periods of summation. They first examined the temporal variability of the series by fitting a statistical model in order to characterize its variability. An IMA (0,1,1) model suitably describes long-range variability in the summed precipitation data, and can be formally decomposed into a stationary white noise contribution and a non-stationary random walk contribution. This means that the long-term precipitation regime can be described in terms of three distinct ranges. The first and narrowest of these accounts for about 2.5 percent of the occurrences of dry weather in Estonia. The second covers about 95% of the observations made during the past 45 years. This range may be described on the basis of a sufficiently large number of observations. The third range corresponds to excessive precipitation, and accounts for 2.5 percent of observations. Nevertheless, these outliers account for only a small fraction of the measured sums, and they span a large range of values in comparison to the central range.

Arun *et al.* (2012) was studied the changing trend of rainfall of a river basin of Orissa near the coastal region. It is facing adverse effects of flood almost every year. This is an effort to analyze one of the most important climatic variable i.e. precipitation, for analyzing the rainfall trend in the area. Daily rainfall data of 40 years from 1971 to 2010 has been processed in the study to find out the monthly variability of rainfall for which Mann-Kendall (MK) Test, Modified Mann-Kendall Test have been used together with the Sen's Slope Estimator for the determination of trend and slope magnitude. Monthly precipitation trend has been identified here to achieve the objective which has been shown with 40 years of data. There was rising rates of precipitation in some months and decreasing trend in some other months obtained by these statistical tests suggesting overall insignificant changes in the area.

Carmen and Alina 2012) analyzed temporal characteristics of precipitation evolution in Dobrudja, a region situated in the Southeastern part of Romania by using a data base of ten monthly series, collected in the period January 1965 to December 2005. They described different methods to detect the break points existence in order to detect changes in evolution of the monthly precipitation series. The study indicates a constant trend of precipitation before 2000 and an increasing one after 2000, in concordance with the predictions for this region.

Choudhury *et al.* (2012) have been analyzed long time (1983-2010) weather variables to detect trend changes using non-parametric Mann Kendall test in mid altitude of Meghalaya (Umiam: 250 41/ N latitude, 910 55/ E longitude, 1010m msl). Results revealed that total annual rainfall trend increased non-significantly at the rate of 3.72mm $year^{-1}$. Contribution of monsoon months declined marginally at the rate of 1.70 mm while pre and post- monsoon months increased non-significantly at an annual rate of 3.18 mm and 1.16 mm, respectively. Probability analysis showed a high frequency of anomalies ($p$>0.6) of either deficit or excess in occurrence of normal monsoon rainfall. Number of rainy days and extreme rainfall events (RX1 day maximum >100mm) exhibited a non-significant increasing trend at 1.7 days and 1.9 days per decade, respectively. Maximum temperature reflected a linear, significant rising trend (+ 0.0860C year$^{-1}$) while minimum temperature enumerated a non-significant decreasing trend (-0.0110C year$^{-1}$). Mean temperature also manifested a significant rising trend at an annual rate of 0.0310C while annual evaporation loss significantly decreased (at 5.75 mm year$^{-1}$). Correlation studies affirmed that atmospheric evaporative demand was relatively more sensitive to changes in sunshine duration(r=+0.63) followed by wind speed (r=+0.41) and vapour pressure deficit (r=-0.11). Climatic water balance studies (rainfall and PET) reflected an increasing trend of water surplus during May to July (Z: +0.08 to 1.56) whereas a reverse trend (declining, Z: -0.56 to -0.87) was observed during post monsoon months (December to February).

Haroon and Afzal (2012) were conducted research to understand the variability of sea surface temperature over the Arabian Sea and its relationship with local and global climatic parameters. It is evident from the multivariate analysis of sea surface temperature (SST) over the selected domain of Arabian Sea that there were four spatial and temporal patterns which were dominant over the Arabian Sea and those modes account more than 90% of the total variability. Since first leading spatial mode (EOF1) and its associated temporal mode (PC1) accounts 64% variability in the data, therefore it is considered as the main dominant mode which is showing warming over the Arabian Sea mainly in the last fifteen years. Further analysis is carried out by comparing first temporal mode (PC1) of SST with local climatic indicators (Temperature & Precipitation) and global climatic indicators (ENSO & PDO).This investigation shows that SST (PC1) variation has a negative relation to both precipitation and temperature of Pakistan. A significant negative correlation is observed between SST (PC1) and Multivariate ENSO index (MEI) and no relationship is found between SST (PC1) and Pacific Decadal Oscillation (PDO).

Arun *et al.* (2012) studied on the changing trend of rainfall of a river basin of Orissa near the coastal region. That was an effort to analyze one of the most important climatic variable i.e. precipitation, for analyzing the rainfall trend in the area. To find out the monthly variability of rainfall for which Mann-Kendall (MK) Test have been used. In the Mann-Kendall test the Zc statistics revealed that the trend of the series for 40 years for individual 12 months from January to December which are 0.652, -1.56, 0.594, 0.315, 0.198, 0.804, -0.711, -1.247, 1.34, 0.408, 1.363 and -0.827 respectively. For January, May, June, September, October and November there is an evidence of rising trend while Zc value is showing negative trend in February, March, April, July, August and December. Thus Zc values for six months show a positive trend and for other six months it shows negative trend representing almost non-significant condition.

Sivakumar *et al.* (2012) analyzed the trend of the climatic parameters (2001-2007) in northeastern zone of Tamilnadu and reported that rainfall increased during 2001 to 2005 and decreased during 2006 while temperature showed same trend. Temperature, rainfall, relative humidity and wind velocity had positive regression when compared with the years (2001-2007).

Syed *et al.* (2012) observed that rain fall pattern, daily minimum and maximum temperatures and humidity are the main factors that constitute the climate of an area. The objective of the current study was to investigate the recent trends and variability of annual minimum, maximum and mean temperatures, relative humidity and rainfall of Peshawar. Annual meteorological parameters for 30-years (1981-2010) of Peshawar observatory have been analyzed to determine indications of variations from long-term averages. For this purpose, Mann-Kendall test was applied to Meteorological data of Peshawar (1981-2010) to study any trend, which were revealed to be in a mixture. The final results show that rainfall is decreasing, minimum temperature, mean temperature and relative humidity are increasing and maximum temperature has no change. Trends found may have negative implications for agriculture, health and socioeconomic conditions of the region that require the attention from relevant stakeholders.

Syeda and Nasser (2012) have been made an attempt to investigate the trend and variability pattern for annual and seasonal (Three crop seasons) average sunshine-hours (ASSH) for six divisional stations of Bangladesh: Dhaka, Khulna, Rajshahi, Barisal, Sylhet and Chittagong. The monthly ASSH (2008-2011) are forecasted applying the univariate Box-Jenkin's ARIMA (autoregressive integrated moving average) modeling technique on the basis of the minimum root mean square forecasting error. The significant negative rates are observed for linear trend (LT) of Annual and Seasonal ASSH in all the six stations with only one minor positive rate for Prekharif season in Khulna. The findings support that the climate of Bangladesh is changing in terms of sunshine-hour which may have tremendous effects in the agricultural production.

Laskar *et al.* (2013) were studied some statistical characteristics of fog, such as frequencies of occurrence, time of onset, duration, intensity and time of dispersal over Patna airport by making use of 10 years data for the period November-February, 2000-2010. The result shows that during the last ten years frequency of fog over Patna airport has increased significantly in all the four months as compared to the climatology based on available synoptic and current weather observations during 1961-90 and 1951-80. The most favorable month for occurrence of fog over Patna airport has been identified as December followed by January. Percentage frequency is highest for duration of fog for more than 5 hours in the months of December and January whereas in the months of November and February frequency is highest for duration less than 2 hours. The formation of fog mostly observed during 0000-0200 UTC and dissipation during 0200-0500 UTC. Percentage frequency of very thick fog was found to be highest in the month of November. In the months of December and January in most of the cases Fog Stability Index (FSI) based on 1200 UTC radiosonde data leading to occurrence of fog during following night/morning has been found to be less than 40.

Mandal *et al.* (2013) have been analyzed weather variables of the island (1982–2010) to detect the changes in trend using Mann–Kendall non parametric test and the magnitudes of such trends have been estimated using Sen's slope. The island receives an annual average rainfall of 1735 ± 352 mm, with an inter-annual deviation exceeding 40% and exhibits a decreasing trend (–5.79 mm year$^{-1}$). Significant ($P < 0.05$) anomalies in inter- as well intra-annual rainfall distributions (pre-monsoon, monsoon and post-monsoon months) were observed. Contribution of monsoon and post-monsoon months showed a decreasing trend (–3.84 to –4.42 mm year–1), while pre-monsoon rainfall showed an increasing trend (+ 0.98 mm year–1). Wide variability in inter annual rainy days (76–139 days) and a decreasing trend (–0.24 days year$^{-1}$) may further complicate the existing anomalies. The island is experiencing a significant ($P$ < 0.05) rising trend of inter-annual mean (+ 0.021°C year–1) and maximum temperatures (+ 0.060°C year–1), with a reverse trend (decline) in minimum temperature (–0.031°C year–1). Other weather variables like sunshine duration, wind speed, atmospheric evaporative demand, etc. also manifested a complex interaction and significant ($P$ < 0.05) decreasing trend over the study periods (1982–2010). Implications of these changes were manifested on water balance front: rising trend of water scarcity during post-monsoon months (December–February) in the island.

Piticar and Ristoiu (2013) were investigated the spatial distribution and temporal variability of precipitation in northeastern Romania for a period of 50 years (1961-2010) by using monthly data from 10 meteorological stations. Mann-Kendall test and Sen's slope estimator was used to analyze the temporal evolution of precipitation time series. The analysis of annual time series shows increasing trends of precipitation amounts in the analyzed area. Seasonal analysis indicates increasing precipitation in summer and autumn time series and decreasing in winter and spring. However, most of the trends are statistically insignificant.

Sushma and Hosalikar (2013) were found observational evidence points to a warming trend in surface temperatures over the globe. This paper focuses on the trends in Maximum and Minimum temperatures over Mumbai. The temperature trends were investigated at different temporal scales from decadal to daily. The seasonal series were also investigated for trends in frequency of occurrences of extreme events. In general an increasing trend is observed over Mumbai, with the increase in Maximum temperatures more than the Minimum temperatures and statistically significant at 95 percent confidence level. A seasonal distinction is evident with the warming more in the winter and Post Monsoon seasons as compared to the Pre Monsoon and Monsoon seasons at both the inter-annual and intra-seasonal scales of investigation. The seasonal distinction was also evident in the extreme temperature analysis. The frequency of occurrences in the hot days and hot nights were more pronounced in the Pre Monsoon and Monsoon seasons as compared to the winter and Post Monsoon seasons. Symmetric warming trend was observed for both the daytime and nighttime temperatures at both the stations in all the seasons though the variations at Santacruz are statistically insignificant in the Post-Monsoon season.

Syeda (2013) was made an attempt to investigate the trend and variability pattern for annual and seasonal (Three crop seasons) total rainfall (TR) for all the six divisional stations in Bangladesh: Dhaka, Rajshahi, Khulna, Barisal, Sylhet and Chittagong. The monthly TR (2009-2012) is forecasted using univariate Box-Jenkin's ARIMA (autoregressive integrated moving average) modelling technique on the basis of minimum root mean square forecasting error. The rates of linear trend for annual TR were found positive for all the stations where the rate was significant for Khulna (5.82 mm/yr) only.

The fairly high rates were observed for Dhaka (4.77) and Sylhet (2.83 mm/yr) with abnormal and/or no stationary residuals while the low rates were documented for Barisal, Chittagong and Rajshahi. During Kharif season, the positive rates are established for Dhaka (2.09) and Khulna (3.63 mm/yr) while negative for other four stations. During and Rabi seasons, the rate was again approved positive except Rabi season of Rajshahi (negative). The findings support that the climate of Bangladesh is changing in terms of total yearly rainfall which will affect its agriculture in different ways.

Asmita and Arya (2014) were analyzed seasonal and annual rainfall data of the stations: Akluj, Baramati, Bhor and Malsiras stations located in Nira Basin, Central India, for studying trend and periodicity using 104 years' rainfall data. The analysis was carried out by using Mann-Kendall (MK), Modified Mann- Kendall (MMK) and Theil and Sen's slope estimator tests describing rising trend at all the stations. However, it is statistically significant at Akluj and Bhor stations at 10% significance level. Bhor station showed the maximum increase in percentage change *i.e*. 0.28 percent in annual rainfall. Monsoon and post-monsoon seasonal rainfall shows a rising trend while the summer and winter seasonal rainfall shows a falling trend. Wavelet analysis showed prominent annual rainfall periods ranging from 2 to 8 years at all the stations after 1960s resulting in describing more changes in the rainfall patterns after 1960s.

## 2.2 Impact of weather parameters on ragi and sugarcane productivity

Ajay Kumar *et al.* (2014) reported that climatic factors have a statistically significant impact on productivity of most of food grain crops but this effect varies across crops. Productivity of rice, maize, sorghum, and ragi crops negatively influenced with increase in actual average maximum temperature. Actual average minimum temperature has negative and statistically significant effects on wheat, barley, gram, and rice crops. Productivity of barley, rice, maize, and ragi crops lead to declined due to excessive rain and changing in rainfall pattern. Estimates suggest that the agricultural productivity in India is sensitive to climate change which is adversely affecting the food grain productivity and it may become a serious threat to food security in India. Major finding of present study indicates a need to adapt separate policies for various crops to mitigate the adverse effect of climate change in India. The results also highlight the important of irrigation and optimum use of fertilizer to mitigate the adverse effect of climate change. The study also suggests that policy makers should ensure adequate and consistent pricing for the farmer's product during the harvesting season.

Cyprien and Vinod Kumar (2011) reported that the panicle number and panicle weight are found to have positive direct effects on the grain yield of rice. The residual factors to grain yield are observed to be quite high. This means that the grain yield is much affected by other components e.g. weather, soil fertility, irrigation etc. than the panicle number, panicle weight components etc.

Pooja Dhuppar *et al.* (2013) conducted micro-level location specific study to understand the impact of weather changes on lentil crop production at Agra. The average maximum (26.1ºC) and minimum temperature (10.4ºC) at cropping period (October-March) for the three years (2001-03) was considered as a base line for the purpose of analysis of 10 years' weather data. The deficit of rainfall (25.7 mm) along with increase in maximum and minimum temperature by 0.4º and 0.6ºC resulted in considerable abiotic stress on lentil crop production. Flower drop/pod drop in lentil increased during the observation period and abiotic stress may be the major cause of concern for lowering of yield. The estimated yield losses may be as follows (a) deficit in 10 mm rainfall can result in yield loss of 60.6 kg/ha, and (b) increase in maximum and minimum temperature by 0.1ºC can result in yield loss of 38.9 and 25.9 kg/ha, respectively.

Patel *et al.* (2013) carried out a study to determine the genetic variability, correlation and path coefficient analysis of lint yield and component characters. The genotypes showed a wide range of variability for all the characters. All the characters except boll weight showed positive and significant correlation with lint yield at genotypic and phenotypic levels. Lint yield, number of bolls per plant and number of monopodia per plant had moderate to high heritability estimates coupled with high genetic advance. It was suggested that these characters could be considered as selection criteria in improvement of lint yield of G. hirsutum.

Tomar (2010) conducted field experiment during 2004-05 and 2005-06 to study the effect of weather factors on Aphid population in cotton. He recorded Aphid population for the first time in $28^{th}$ standard week, which remained active up to $1^{st}$ standard week having its peak density in $37^{th}$ weak. Weather parameters namely maximum and minimum temperature and relative humidity showed positive correlation with aphid population and also increased at the rate of 1.3181, 0.5406 and 0.1939 per leaf with $1^{0}$C increase in minimum and maximum temperature and 1 percent increase in relative humidity, respectively. The direct contribution of minimum temperature was substantially positive and highest followed by maximum temperature. Most of the weather parameters exerted their indirect contribution to the aphid population through minimum temperature.

Melesse and Zewotir (2013) identified that due to increasing wood consumption and pulp and paper demands, plantations of fast growing tree species, have a growing importance for the sustainability of industrial wood raw material. Consequently, the efficient utilization of fast growing plantations can have a large impact on productivity. They have made an attempt to determine the factors that influence stem radial growth of juvenile Eucalyptus hybrids grown in the east coast of South Africa. Measurement of stem radius was conducted using dendrometers on sampled trees of two Eucalyptus hybrid clones. Daily averages of climatic data were simultaneously collected with total rainfall from the site. In this study, path analysis was employed. The joint effect of the climatic variables as well as the direct effect of each climatic variable was studied. It is found that all variables had a positive effect on stem radial growth. The study showed that tree age is the most important determinant of radial measure.

# III. MATERIALS AND METHODS

The study was undertaken with an overall objective of studying the variability of weather parameters and their impact on the productivity of ragi and sugarcane in Mandya district during the period 1986-2010. In this chapter an emphasis is made to provide a brief description of materials and methods of statistical analysis employed in the present study.

The methodology is presented under the following sub headings.

3.1. Description of the study area.

3.2. Data base.

3.3. Analytical tools and techniques applied.

## 3.1. Description of the study area

The present study was carried out to know the trend and temporal variation of weather parameters in Mandya District of Karnataka state.

Mandya is located at 12.52°N 76.9°E and in the south east of Karnataka State. It has an average elevation of 695 meters above mean sea level. Majority of Geographical area of Mandya district is covered by Cauvery basin and agriculture in the district is classified under agro-climatic zone-6 (Southern dry Zone). The average annual rainfall found to be 700mm.

The total geographical area of the Mandya district is 4,98,244 hectares, out of which 2,48,825 hectares forms the sown area. More than half of the total land area in the district is under agricultural use. The total irrigated area is 1,16,901 hectares, out of which around 88,000 hectares is being irrigated by K. R. Sagar and around 16,000 by Hemavathi reservoir. The rest of the land is irrigated by other sources like tanks, wells and bore wells.

## 3.2. Data base

The secondary data on the weather parameters for the period 1986-2010 (25 years) were collected from the Zonal Agricultural Research Station, Vishveswaraiah Canal Farm, Mandya. The data on productivity of ragi and sugarcane were collected from 1991 to 2010 (20 years). Further the crop data were divided into two periods, first comprising of 1991-2000 and second period classified between 2001- 2010 for normality test.

**Yield**

$V_1$: Ragi (q/ha)

$V_2$: Sugarcane (t/ha)

**Weather Parameters**

The average monthly data were collected over 25 years from 1986-2010 for the following weather parameters.

$Y_1$: Maximum temperature ($^0$C)

$Y_2$: Minimum temperature ($^0$C)

$Y_3$: Ralative Humidity (%)

$Y_4$: Cloudiness (Oktas)

$Y_5$: Wind speed (Km/hr)

$Y_6$: Sun Shine (hr)

$Y_7$: Rainfall (mm)

### 3.2.1 Measurement of Variables

All the selected seven weather parameters recorded at Zonal Agricultural Research Station, Vishveswaraiah Canal Farm, Mandya were cosidered and procedure shown below.

**$Y_1$: Maximum temperature**

The Maximum temperature was measured by using mercury thermometer in max. degree Celsius every day.

**$Y_2$: Minimum temperature**

Minimum temperature was measured by using alcohol thermometer in min. degree Celsius every day.

**$Y_3$: Ralative Humidity**

Relative humidity was measured by using sling psychrometer and recorded in percentage in the early morning every day.

**$Y_4$: Cloudness**

Cloudness was measured by using ceilometer and recorded in oktas every day.

**$Y_5$: Wind speed**

Wind speed was measured by using anemometer and recorded in Km/hr every day.

**$Y_6$: Sun Shine Hours (SSH)**

SSH was measured by means of Campbell stokes sunshine recorder in hours every day.

**$Y_7$: Rainfall**

Rainfall was measured by using rain guage in mm every day.

## 3.3. Analytical tools and techniques applied

In this section, a brief description of statistical methods employed is presented. Keeping in the view of the objectives formulated for the study, the following tools and techniques have been employed.

3.3.1. To study the trend in the weather parameter over the study period

3.3.2. To assess the impact of weather parameters on productivity of ragi and sugarcane

### 3.3.1. To study the trend in the weather parameter over the study period

To assess the trend of weather parameters, the following statistical tools were used.

#### 3.3.1.1. Descriptive statistics

The descriptive statistics such as the Mean, Standard Deviation (SD), Coefficient of variation (CV), First quartile ($Q_1$), and Third quartile ($Q_3$) were computed for each of the selected weather parameters and in turn used to study the variability of the weather parameters in Mandya District. The standard formulae were used to compute the various measures.

#### 3.3.1.2. Model Adequacy Checking

Adequacy of a model depends on the validity of assumptions underlying the model. The assumptions made in a linear regression model are, apart from linear-dependence of 'Y' on regressors, independence and identical distribution (normal) of regressors with zero mean. Gross violations of the assumptions may yield an unstable model in the sense that a different samples could lead to a totally different model with opposite conclusion. We cannot detect departures from the underlying assumptions by examination of the summary statistics such as 't' or 'F' statistics or $R^2$ (Draper and Smith, 1981). These are "Global" model properties, and as such they do not ensure model adequacy. Hence, diagnostic methods, primarily based on study of the model residuals are used. The diagnostics checks are used for randomness and normality of residuals.

**Assumptions of Error Term**

An important assumption of Linear regression is that the residual, $\varepsilon$ follows normal distribution. This assumption is required for test of hypothesis about the regression coefficients. This assumption usually verified using

##### 3.3.1.2.1 Test for Normality

(1) Shapiro-Wilk test
(2) Anderson-Darling test

#### 3.3.1.2.1.1 Shapiro-Wilk test (W)

This is the standard test for normality. The test statistic W is the ratio of the best estimator of the variance (based on the square of a linear combination of the order statistics) to the usual corrected sum of squares estimator of the variance. 'W' may be thought of as the correlation between given data and their corresponding normal scores. The value of 'W' ranges from 0 to 1. When W = 1 the given data are perfectly normal in distribution (Shapiro, *et al.* 1968). When 'W' is significantly smaller than 1, the assumption of normality is not met. A significant 'W' statistic causes to reject the assumption that the distribution is normal. Shapiro-Wilks 'W' is recommended for small and medium samples up to n = 2000

NH ($H_0$): A sample $x_1, ..., ,x_n$ is from a normally distributed population.

AH ($H_1$): A sample $x_1, ..., ,x_n$ is not from a normally distributed population.

The test statistic is

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

Where,

$x_{(i)}$ is the $i^{th}$ order statistic, i.e., the $i^{th}$-smallest number in the sample;

$\bar{x} = (x_1 + ... + x_n)/n$ is the sample mean;

the constants $a_i$ are given by

$$(a_{1,...,}a_n) = \frac{m^T V^{-1}}{(m^T V^{-1} V^{-1} m)^{1/2}}$$

Where,

$$m = (m_{1,...,}m_n)^T$$

and $m_1, ..., m_n$ 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.

Then values $a_i$, coefficients are tabulated by Shapiro and wilk (1965).

Reject the null hypothesis if $W$ is too small (near to zero).

#### 3.3.1.2.1.2 Anderson-Darling test

The Anderson-Darling test (Stephens, 1974) is used to test if a sample of data comes from a specific distribution. It is a modification of the Kolmogorov-Smirnov (K-S) test and gives more weight to the tails of the distribution than does the K-S test. The K-S test is distribution free in the sense that the critical values do not depend on the specific distribution being tested. The Anderson-Darling test makes use of the specific distribution in calculating critical values. This has the advantage of allowing a more sensitive test and the disadvantage that critical values must be calculated for each distribution.

Stephens (1974) found $A^2$ to be one of the best EDF (Empherical distribution function) statistics for detecting most departures from normality. The test statistic can then be compared against the critical values of the theoretical distribution (dependent on which $F$ is used) to determine the P-value.

Procedure is as fallows

1) The data $X_i$, for i= 1, 2,….,n is taken from a population, we have to test whether it is from normal distribution or not.

2) The mean ( $\overline{X}$ ) and standard deviation (S) are calculated from the sample of $X$.

3) The values $X_i$ are standardized as

$$Y_i = \frac{X_i - \overline{X}}{s}$$

4) The test statistic $A^2$ is calculated using

$$A^2 = -n - \frac{1}{2}\sum_{i=1}^{n}(2i-1)(\ln \Phi(Y_i) + \ln(1-\Phi(Y_{n+1-i})))$$

Where,

$\Phi$ ($Y_i$): Standard normal CDF (cumulative distribution function)

n: Sample size

The test statistic can then be compared against the critical values of the theoretical distribution (dependent on which '$F$' is used) to determine the P-value.

Note:

1) $A^{*2}$, an approximate adjustment for sample size, is calculated using

$$A^{*2} = A^2\left(1 + \frac{0.75}{n} + \frac{2.25}{n^2}\right)$$

If $A^{*2}$ exceeds 0.752 then the hypothesis of normality is rejected for a 5 percent level test.

2) If S = 0 or any $\Phi$ ($Y_i$) = (0 or 1) then $A^2$ cannot be calculated and is undefined.

**3.3.1.2.2 Test for Randomness (Run test)**

Randomness of residuals is tested using the non-parametric one sample run test (Siegel and Castellan, 1988).

Run is defined as a sequence of like events or symbols that is precede and followed by an event or symbol of a different type or by none at all. The hypothesis as

$H_0$ : The sequence is random
$H_1$ : The sequence is not random

Let ‘m’ be the number of elements of one kind, and ‘n’ be the number of elements of the other kind in a sequence of N = m + n binary events. If both m and n are less than or equal to 20, then if the number of runs ( r ) falls between the critical values, we cannot reject null hypothesis.

If either ‘m’ or ‘n’ is larger than 20, a good approximation to the sampling distribution of ‘r’ is the normal distribution with,

$$Mean(\mu_r) = \frac{2mn}{N} + 1$$

And

$$\text{Standard Deviation } (\sigma_r) = \sqrt{\frac{2mn(2mn - N)}{N^2(N-1)}}$$

Further, $H_0$ is tested using,

$$Z = \frac{(r \pm 0.5) - \mu_r}{\sigma_r}$$

The significance of any observed value of ‘Z’ computed using the equation may be determined from a normal distribution table.

### 3.3.1.3. Trend analysis

Trend analysis was done by fitting the different types of regression equations such as Linear, Exponential and logarithmic models separately for each parameter for individual month over the study period of 1986-2010. Further, the trend lines were presented by using graphs of free hand curve fitting to know the trend of weather parameter over time. The best fit model is one which posses the highest $R^2$ value.

The models used for developing the best fit are as follows:

a) **Linear model:** Linear model is fitted for all the selected weather parameters considering the period 1986-2010 for each month (January to December). The linear model is as follows;

$$Y = b_0 + b_1 X + e$$

Where,
$b_0$ : Intercept
$b_1$ : Slope
X : Time period

Y: Maximum temperature, Minimum temperature, Rainfall, Relative humidity, Cloudiness, Wind speed, Sun shine hours (one parameter at a time has been taken).

$e_i$ : Error component

**b) Exponential model:** Exponential model is fitted for all mentioned weather parameters considering the period 1986-2010 for each month. The linear model is as follows;

$$Y = b_0 \ Exp(b_1 X) + e$$

Where,

$b_0$ and $b_1$: Constants to be estimated.

X : Time period.

$Y_i$ : Maximum temperature, Minimum temperature, Rainfall, Relative humidity, Cloudiness, Wind speed, Sun shine hours (one parameter at a time has been taken).

Exp. : Exponential function.

e : Error component.

**c) Logarithmic model:** Logarithmic model is fitted for all mentioned weather parameters considering the period 1986-2010 for each month. The Logarithmic model is as follows;

$$\ln Y = \ln b_0 + b_1 \ln(X)$$

Where,

$b_0$ and $b_1$: Constants to be estimated.

$Y_i$ : Maximum temperature, Minimum temperature, Rainfall, Relative humidity, Cloudiness, Wind speed, Sun shine hours (one parameter at a time has been taken).

X : Time period.

#### 3.3.1.4 Regression analysis

The climatic change is assessed by relating weather parameters on time period for each month and also combining through functional forms. Thus regression models became the usual choice.

#### 3.3.1.4.1 Data for Regression

Data on the weather parameters say $Y_1$, $Y_2$, $Y_3$, $Y_4$, $Y_5$, $Y_6$, and $Y_7$ are used as dependent variables and time period 'X' as independent variable.

#### 3.3.1.4.2 Simple regression model

The simple regression models are fitted using weather parameters ($Y_1$, $Y_2$,…,$Y_7$) as dependent variables one at a time and time period (X) as independent variable.

$$Y_i = \beta_0 + \beta_1 X_i + e_i$$

Where, i=1, 2, 3,…,7

### 3.3.1.4.3 Testing significance of regression coefficient ($\beta_{YX}$)

Significance of regression coefficient was tested by t-test.

**(a) Hypothesis:**

$H_0$ : $\beta_{yx}=0$

$H_1$ : $\beta_{yx} \neq 0$

**(b) Test statistic:**

$$t_{cal} = \frac{b_{yx}}{\text{Std. error of } b_{yx}}$$

Where,

$$\text{Std error} = \sqrt{\frac{MSE}{S_{xx}}}$$

$b_{yx}$ : Regression coefficient,

$S_{xx}$ : Sum of squares of independent variables,

MSE : Mean sum of square of error term.

**(c) Critical region:**

Reject $H_0$ at α% level of significance if $|t_{cal}| \geq t_{(n-2,\ \alpha/2)}$

### 3.3.1.4.4 Coefficient of determination ($R^2$)

The statistic $R^2$ indicates the percentage of variation in the dependent variable explained by the independent variables included in the regression model. $R^2$ is computed using uncorrected sum of squares.

$$R^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

Where, $0 \leq R^2 \leq 1$

## 3.3.2. To assess the impact of weather parameters on productivity of ragi and sugarcane

### 3.3.2.1 Correlation analysis

Pearson correlation coefficients were computed between all above mentioned weather parameters and productivity of ragi and sugarcane for twenty years data (1991-2010).

### 3.3.2.1.1 Karl-Pearson's correlation coefficient ($r_{yv}$)

$$\boldsymbol{\rho_{yv} = \text{corr}(y, v) = \frac{\text{cov}(y, v)}{\sigma_y \sigma_v} = \frac{E[(X - \mu_Y)(Y - \mu_V)]}{\sigma_y \ \sigma_v}}$$

$cov(y, v)$= Covariance between weather variables
$\sigma_y$ = Standard deviation of weather parameters (Y)
$\sigma_v$ = Standard deviation of ragi and sugarcane (V)

### 3.3.2.1.2 Testing significance of correlation coefficient

Significance of correlation coefficient was tested by t-test.

**(a) Hypothesis:**

$H_0 : \quad \rho_{yv} = 0$
$H_1 : \quad \rho_{yv} \neq 0$

**(b) Test statistic:**

$$t_{cal} = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \sim t_{\alpha,(n-2)df}$$

Where,

'r' is correlation coefficient commutated from the sampled data.
(n-2) is degree of freedom.

**(c) Critical region:**

Reject $H_0$ at α% level of significance if $|t_{cal}| \geq t_{(n-2, \alpha/2)}$

### 3.3.2.2 Path Analysis

To examine the influence of the weather parameters namely maximum temperature, minimum temperature, relative humidity, cloudiness, wind speed, sun shine hour and rainfall on the productivity of ragi and sugarcane, we used path analysis. Through the path analysis we can identify the direct and indirect effect of weather parameters on the productivity of ragi and sugarcane.

Path analysis furnishes a method to determine the direct and indirect effects of weather parameters on the productivity of ragi and sugarcane. Path analysis is a standardized partial regression and it is a technique to elucidate the contribution of each variable to the total correlation coefficient. It quantifies direct and indirect effects of each variable and thus helps to visualize correlation in its totality to determine selection indices. The correlation coefficients of ragi and sugarcane productivity with different weather parameters were further partitioned into direct and indirect effects. It involves a set of simultaneous regression equations that theoretically establish the relationship among observed variables in the path model. Path analysis extends the idea of regression modeling and gives the flexibility of quantifying indirect and total causal effects in addition to the direct effect which is also possible in regression analysis (Bollen, 1989). Path analysis however gives more flexibility and predictor variables are allowed to influence the outcome variable directly as well as indirectly.

Path analysis is an extension of the regression model, which researchers use to test the fit of a correlation matrix with a causal model that has been, tested (Garson, 2004). The aim of path analysis is to provide estimates of the magnitude and significance of the hypothesized causal connections among sets of variables displayed through the use of path diagrams.

**Path Diagram**

The graphical or diagrammatical presentation of path analysis is known as path diagram. Generally arrows are used to show the relations, a single headed arrow is meant for showing cause to effect. In path diagram there are two kinds of variables, the independent variables known as the casual variables and the dependent variables known as endogenous variables.

If Y is a character, which is linearly determined by correlated variables $X_1$, $X_2$ and $X_3$, because of the closed syste, a path diagram can be formulated as in fig. 3.1

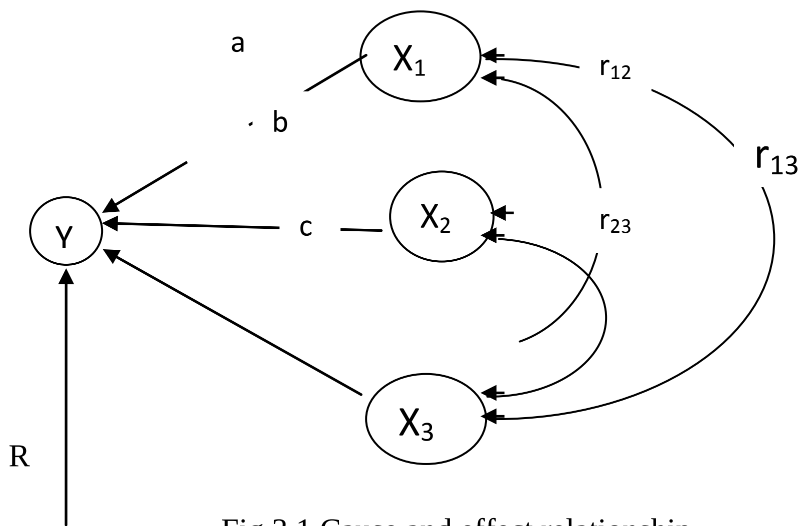


Fig 3.1 Cause and effect relationship

Symbols a, b, and c in the fig 3.1 represent path coefficients from causes $X_1$, $X_2$ and $X_3$, respectively, $r_{X1X2}$, $r_{X2X3}$ and $r_{X1X3}$ are the correlation coefficients and R is variation in Y that is due to those agencies which are not known (residual). It is convention to use a double headed arrow for correlation coefficient and unidirectional arrow for the direct path of influence from one variable in the system to the dependent variable.

A character Y is determined by three correlated variables, *viz*. $X_1$, $X_2$ and $X_3$. The relationship can be expressed in the form of a partial regression equation and is given by

$$\mathbf{Y=\mu+\beta_1 X_1+\beta_2X_2 + \beta_3X_3+R.}$$

Where,

$\beta_1$, $\beta_2$ and $\beta_3$ are the partial regression coefficients. $\beta_1$ is the partial regression coefficient of Y on $X_1$, measures the amount of change that can be brought about in Y due to one unit change in $X_1$ and $X_2$, $X_3$ are held constant. $\beta_2$ and $\beta_3$ have similar meanings. R is the residual component. When the variables are expressed as deviation from their respective means and also in terms of standardized units, their means will be zero and variance will be equal to unity. Thus, if we denote $(X_1 - \overline{X}_1)/\sigma_Y$ is denoted by a lower case letter $x_1$, mean of $x_1$'s will be zero and the variance unity. Replacing the expression $\beta_1 \sigma_{X_1}/\sigma_Y$ by term 'a' which is a standardized partial regression coefficient is called as the "path coefficient". It should be pointed out that the path coefficients have a direction similar to the regression coefficients, i.e., they may bear a positive or a negative sign. Unlike the correlation coefficients, the path coefficients could be greater than or lesser than unity like regression coefficients.

A set of three simultaneous equations is then formulated from the path diagram as:

$$r_{YX_1} = a + br_{X_1X_2} + cr_{X_1X_3}$$

$$r_{YX_2} = ar_{X_2X_1} + b + cr_{X_2X_3}$$

$$r_{YX_3} = ar_{X_2X_1} + br_{X_3X_2} + c$$

Where,

$r_{X1x2}$ – Estimates of simple correlation coefficient between $x_1$ and $x_2$ variables.
$r_{x2x3}$ – Estimates of simple correlation coefficient between $x_2$ and $x_3$ variables.
a- Direct effect of variable $X_1$.
b - Direct effect of variable $X_2$.
c - Direct effect of variable $X_3$.
y - Dependent variable.

Information provided in the above equation can be arranged in the matrix form as:

$$\begin{pmatrix} r_{YX_1} \\ r_{YX_2} \\ r_{YX_3} \end{pmatrix} = \begin{pmatrix} 1 & r_{X_1X_2} & r_{X_1X_3} \\ r_{X_1X_2} & 1 & r_{X_2X_3} \\ r_{X_1X_3} & r_{X_3X_2} & 1 \end{pmatrix} \begin{pmatrix} a \\ b \\ c \end{pmatrix}$$

C = A B

Matrix A is symmetrical about the diagonal elements. The diagonal elements in this matrix represent the direct effects of $X_1$, $X_2$ and $X_3$, respectively on Y. All the direct effects have been replaced by unity in this matrix. Elements of the column matrix B specify the path coefficients to be estimated. The column matrix C represents the estimated values of correlation coefficients between dependent variable Y, and the component variables, i.e., $X_1$, $X_2$ and $X_3$. Estimates of unknown are, calculated as:

$$B=A^{-1}C$$

Where,

$A^{-1}$ - The inverse of matrix A.

C - Estimated values of correlation coefficients between dependent variable and independent variable.

The indirect effects are calculated from the three simultaneous equations, after substituting the values of a, b and c in these equations, path coefficients can be estimated. This method can permit to identify relatively important components of a dependent variable, on the basis of their direct and indirect influences.

Besides the direct effect of the exogenous ($X_1$) on the endogenous (Y), there is indirect effect of X on Y via other x's by virtue of its relationship with others. A change in a variable, say $X_1$, will affect its linear correlation $r_{12}$, with another variable, $X_2$, which invariable affects Y. Let $P_i$ be the direct effect of $X_i$ on Y, and change is only partial and proportional to $r_{12}$. That is, $r_{ij}p_j$ is an indirect effect of $X_i$ via $X_j$.

The percentage direct contributions, combined contributions of any two variables and the residual effect are worked out as follows.

a) The direct percentage contribution = $(P_i)^2$ x 100.

b) The combined contributions of any two variables = $2(P_iP_jr_{ij})$.

Where,

$P_i$ – Direct effect of $X_i$ on Y.

$r_{ij}P_j$ – Indirect effect of $X_i$ via $X_j$.

Once the path coefficient values corresponding to different independent variables are worked out the next problem lies in estimating the residual (R) i.e. the unexplained part of the model.

The residual effect is given by:

$$R^2 = 1 - \begin{bmatrix} P_{Y1}^2 + P_{Y2}^2 + P_{Y3}^2 + P_{Y4}^2 + P_{Y5}^2 + P_{Y6}^2 + P_{Y7}^2 + 2r_{12}P_{y1}P_{y2} + 2r_{13}P_{y1}P_{y3} + 2r_{14}P_{y1}P_{y4} + 2r_{15}P_{y1}P_{y5} + 2r_{16}P_{y1}P_{y6} + \\ 2r_{17}P_{y1}P_{y7} + 2r_{23}P_{y2}P_{y3} + 2r_{24}P_{y2}P_{y4} + 2r_{25}P_{y2}P_{y5} + 2r_{26}P_{y2}P_{y6} + 2r_{27}P_{y2}P_{y7} + 2r_{34}P_{y3}P_{y4} + 2r_{35}P_{y3}P_{y5} + \\ 2r_{36}P_{y3}P_{y6} + 2r_{37}P_{y3}P_{y7} + 2r_{45}P_{y4}P_{y5} + 2r_{46}P_{y4}P_{y6} + 2r_{47}P_{y4}P_{y7} + 2r_{56}P_{y5}P_{y6} + 2r_{57}P_{y5}P_{y7} + 2r_{67}P_{y6}P_{y7} \end{bmatrix}$$

Where,

$R^2$ – Residual effect.

$P^2_{Y1}$ – Square of correlation between path co-efficient maximum temperature on productivity of ragi and sugarcane.

$P^2_{Y2}$ – Square of correlation between path co-efficient minimum temperature on the productivity of ragi and sugarcane.

$P^2_{Y3}$ – Square of correlation between path co-efficient relative humidity on the productivity of ragi and sugarcane.

$P^2_{Y4}$ – Square of correlation between path co-efficient cloudiness on the productivity of ragi and sugarcane.

$P^2_{Y5}$ – Square of correlation between path co-efficient wind speed on the productivity of ragi and sugarcane.

$P^2_{Y6}$ – Square of correlation between path co-efficient sun shine hour on the productivity of ragi and sugarcane.

$P^2_{Y7}$ – Square of correlation between path co-efficient rainfall on the productivity of ragi and sugarcane.

# IV. RESULTS

This chapter deals with research findings of the study as per the framed methodology were discussed in chapter III. The data have been analyzed and the results are interpreted in accordance with objectives as follows;

4.1 To study the trend in the weather parameter over the study period.

4.2 To study the impact of weather parameters on ragi and sugarcane productivity.

## 4.1 To study the trend in the weather parameter over the study period

### 4.1.1 Descriptive statistics

In order to study the variability of selected weather parameters at Mandya district, the descriptive statistics such as Mean, Standard Deviation and Coefficient of Variation (CV) and Quartiles were computed and the results are presented in the following section.

#### 4.1.1.1 Maximum temperature

The results of temperature for all the months (January to December) over a study period are presented in Table 4.1.1.1.

The results of Table 4.1.1.1 showed that the mean maximum temperature was found to be increases with standard deviation from the month of February (31.23±1.23) to May (33.44±1.35) and thereafter start declining. The coefficient of variation of maximum temperature ranges from 2.66 to 8.29 per cent over all the months.

**Table 4.1.1.1: Mean and Variability of Maximum and Minimum temperature for the Period January- December during 1986-2010**

| Period | Maximum Temperature ($^0$C) | | | | | Minimum Temperature ($^0$C) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | CV | $Q_1$ | $Q_3$ | Mean | SD | CV | $Q_1$ | $Q_3$ |
| Jan | 29.22 | 1.19 | 4.07 | 28.41 | 29.89 | 14.19 | 1.18 | 8.28 | 13.52 | 15.30 |
| Feb | 31.23 | 1.23 | 3.95 | 30.46 | 32.08 | 16.10 | 1.08 | 6.73 | 15.19 | 16.93 |
| Mar | 34.03 | 2.31 | 6.77 | 32.39 | 35.39 | 18.43 | 1.16 | 6.32 | 17.33 | 19.15 |
| Apr | 32.15 | 2.67 | 8.29 | 28.93 | 34.64 | 20.64 | 0.81 | 3.91 | 20.18 | 21.40 |
| May | 33.44 | 1.35 | 4.04 | 33.04 | 34.39 | 20.71 | 0.91 | 4.41 | 20.09 | 21.52 |
| Jun | 32.57 | 2.46 | 7.55 | 30.75 | 35.22 | 20.21 | 0.92 | 4.53 | 19.58 | 20.76 |
| Jul | 29.25 | 0.87 | 2.97 | 28.55 | 30.03 | 19.88 | 0.61 | 3.04 | 19.55 | 20.21 |
| Aug | 28.84 | 0.95 | 3.28 | 28.17 | 29.63 | 19.81 | 0.68 | 3.41 | 19.24 | 20.40 |
| Sep | 29.42 | 0.78 | 2.66 | 28.81 | 30.08 | 19.74 | 0.51 | 2.60 | 19.26 | 20.15 |
| Oct | 29.41 | 1.07 | 3.62 | 28.64 | 29.96 | 19.32 | 0.77 | 3.97 | 18.96 | 19.89 |
| Nov | 28.94 | 1.23 | 4.25 | 27.94 | 29.39 | 17.74 | 1.26 | 7.08 | 16.66 | 18.52 |
| Dec | 28.45 | 1.21 | 4.26 | 27.44 | 29.64 | 15.03 | 0.92 | 6.10 | 14.63 | 15.36 |

CV : Coefficient of variation (%), $Q_1$ : First Quartile, $Q_1$ : Third Quartile

### 4.1.1.1 Minimum temperature

The results of Table 4.1.1.1 showed that the mean minimum temperature increases with standard deviation from the month of January (14.19±1.18) to May (20.71±0.91) and thereafter starts decreases and the coefficient of variation of minimum temperature ranges from 2.60 to 8.28 per cent over the months.

### 4.1.1.2 Relative humidity

The results of Table 4.1.1.2 showed that the mean relative humidity was observed to be more uniform during study period and the coefficient of variation of relative humidity ranges from 1.80 to 5.18 per cent over the months.

### 4.1.1.2 Cloudiness

The results of Table 4.1.1.2 depicts that the mean cloudiness was found to be optimum during study period for all the months except June, July and October. It was noticed that the mean with standard deviation of cloudiness in June (2.09±0.82), July (2.08±0.86) and October (2.17±0.95) there was more cloudiness compared to other months. The coefficient of variation of cloudiness ranges from 28.15 to 56.87 per cent over the months.

**Table 4.1.1.2: Mean and Variability of Relative Humidity and Cloudiness for the Period January- December during 1986-2010**

| Period | Relative Humidity (%) | | | | | Cloudiness (oktas) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | CV | $Q_1$ | $Q_3$ | Mean | SD | CV | $Q_1$ | $Q_3$ |
| Jan | 86.69 | 3.11 | 3.58 | 83.76 | 88.84 | 1.56 | 0.58 | 37.16 | 1.10 | 2.07 |
| Feb | 86.94 | 3.93 | 4.53 | 85.00 | 90.18 | 1.52 | 0.65 | 42.76 | 0.96 | 2.00 |
| Mar | 83.92 | 4.32 | 5.15 | 82.00 | 86.96 | 1.22 | 0.69 | 56.87 | 0.76 | 1.98 |
| Apr | 82.72 | 4.39 | 5.18 | 81.68 | 87.11 | 1.41 | 0.56 | 39.59 | 1.02 | 2.00 |
| May | 85.03 | 3.68 | 4.33 | 82.48 | 87.18 | 1.71 | 0.73 | 42.72 | 1.18 | 2.47 |
| Jun | 86.76 | 3.59 | 4.13 | 84.17 | 89.54 | 2.09 | 0.82 | 39.39 | 1.43 | 2.68 |
| Jul | 87.52 | 2.61 | 2.99 | 86.00 | 89.25 | 2.08 | 0.86 | 41.15 | 1.43 | 3.03 |
| Aug | 87.84 | 3.48 | 3.96 | 85.44 | 90.29 | 1.86 | 0.52 | 28.15 | 1.42 | 2.34 |
| Sep | 87.86 | 3.86 | 4.39 | 86.04 | 91.00 | 1.98 | 0.95 | 47.77 | 1.23 | 2.87 |
| Oct | 89.64 | 1.61 | 1.80 | 88.63 | 91.09 | 2.17 | 0.95 | 43.95 | 1.40 | 2.77 |
| Nov | 88.24 | 2.01 | 2.28 | 87.56 | 89.65 | 1.75 | 0.72 | 40.85 | 1.18 | 2.22 |
| Dec | 87.26 | 3.53 | 4.05 | 84.29 | 90.20 | 1.56 | 0.65 | 41.63 | 1.02 | 2.05 |

CV : Coefficient of variation (%), $Q_1$ : First Quartile, $Q_1$ : Third Quartile

#### 4.1.1.3 Wind speed

The results of Table 4.1.1.3 showed that the mean with standard deviation of wind speed was found to be higher during January (5.21±2.33), June (5.73±1.68), July (6.67±1.78), August (5.37±1.95) and December (5.55±2.01), however noticed less during other months. The coefficient of variation of wind speed ranges from 21.92 to 52.76 per cent over the months.

#### 4.1.1.3 Sun Shine hour

The results of Table 4.1.1.3 indicate that the mean sun shine hour was found to be more during January to May, however less during June to December. The coefficient of variation of sun shine hour ranges from 18.84 to 36.14 per cent over the months.

**Table 4.1.1.3: Mean and Variability of Wind speed and Sun shine hour for the Period January- December during 1986-2010**

| Period | Wind speed (Km/hr) | | | | | Sun shine hour (hr) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | CV | $Q_1$ | $Q_3$ | Mean | SD | CV | $Q_1$ | $Q_3$ |
| Jan | 5.21 | 2.33 | 44.71 | 3.60 | 7.68 | 7.36 | 1.57 | 21.38 | 6.20 | 8.43 |
| Feb | 4.19 | 2.17 | 51.83 | 2.80 | 4.53 | 8.27 | 1.69 | 20.37 | 6.90 | 10.03 |
| Mar | 4.62 | 2.09 | 45.30 | 3.28 | 5.25 | 8.32 | 1.65 | 19.81 | 6.90 | 9.58 |
| Apr | 4.74 | 2.06 | 43.46 | 3.50 | 5.95 | 7.90 | 1.70 | 21.49 | 6.59 | 9.20 |
| May | 4.59 | 1.49 | 32.33 | 3.22 | 6.07 | 7.94 | 1.50 | 18.84 | 6.86 | 8.98 |
| Jun | 5.73 | 1.68 | 29.31 | 4.40 | 7.28 | 6.01 | 1.71 | 28.51 | 4.80 | 6.49 |
| Jul | 6.67 | 1.78 | 26.69 | 4.90 | 8.26 | 5.30 | 1.48 | 27.96 | 4.20 | 6.87 |
| Aug | 5.37 | 1.95 | 36.31 | 3.80 | 7.15 | 4.93 | 1.77 | 35.93 | 3.99 | 5.27 |
| Sep | 4.70 | 1.03 | 21.92 | 3.90 | 5.51 | 5.28 | 1.91 | 36.12 | 3.50 | 6.96 |
| Oct | 4.62 | 2.16 | 46.74 | 3.22 | 5.80 | 5.23 | 1.89 | 36.14 | 3.55 | 6.62 |
| Nov | 4.81 | 2.54 | 52.76 | 2.50 | 6.50 | 5.72 | 2.06 | 36.08 | 3.90 | 7.02 |
| Dec | 5.55 | 2.01 | 36.16 | 4.30 | 7.50 | 6.58 | 1.88 | 28.57 | 4.80 | 7.80 |

CV : Coefficient of variation (%), $Q_1$ : First Quartile, $Q_1$ : Third Quartile

#### 4.1.1.4 Rainfall

The results of Table 4.1.1.4 showed that the mean rainfall with standard deviation was found to be more during May (72.80±60.10), June (66.40±52.80), July (56.00±47.75), August (77.00±64.30), September (120.40±94.30) and October (160±115.80) compared to other months. The coefficient of variation of rainfall ranges from 72.34 to 318.85 per cent over the months.

**Table 4.1.1.4: Mean and Variability of Rainfall for the Period January- December during 1986-2010**

| Period | Rainfall (mm) | | | | |
|---|---|---|---|---|---|
| | **Mean** | **SD** | **CV** | **$Q_1$** | **$Q_3$** |
| Jan | 1.00 | 3.19 | 318.85 | 0.00 | 0.00 |
| Feb | 3.76 | 11.68 | 310.56 | 0.00 | 0.00 |
| Mar | 12.30 | 31.40 | 255.73 | 0.00 | 11.50 |
| Apr | 52.12 | 47.77 | 91.66 | 10.00 | 107.00 |
| May | 72.80 | 60.10 | 82.53 | 28.50 | 104.00 |
| Jun | 66.40 | 52.80 | 79.57 | 24.00 | 103.00 |
| Jul | 56.00 | 47.75 | 85.27 | 22.50 | 87.00 |
| Aug | 77.00 | 64.30 | 83.47 | 25.50 | 124.00 |
| Sep | 120.40 | 94.30 | 78.36 | 50.50 | 172.50 |
| Oct | 160.00 | 115.80 | 72.34 | 67.50 | 212.5 |
| Nov | 48.20 | 59.30 | 23.19 | 10.50 | 75.50 |
| Dec | 19.04 | 35.90 | 88.57 | 0.00 | 28.00 |

CV : Coefficient of variation (%), $Q_1$ : First Quartile, $Q_1$ : Third Quartile

### 4.1.2 Assumptions of Error Term

#### 4.1.2.1 Test for Randomness-Run test

In order to test the adequacy of the model, randomness run test was done. The error terms were evaluated for their randomness using run test, the results of which are presented in the Table 4.1.2.1. The non significant results (P>0.05) indicate that the error terms are randomly distributed for the fitted models.

**Table- 4.1.2.1 Results of test for randomness of error term**

| Parameters | Test value | |
|---|---|---|
| | 1991-2000 | 2000-2010 |
| Max. temp | -0.01 $^{NS}$ | -0.08 $^{NS}$ |
| Min. temp | 0.06 $^{NS}$ | 0.07 $^{NS}$ |
| Relative humidity | 0.06 $^{NS}$ | 0.44 $^{NS}$ |
| Cloudiness | -0.06 $^{NS}$ | 0.00 $^{NS}$ |
| Wind speed | 0.08 $^{NS}$ | 0.01 $^{NS}$ |
| Sun shine hour | 0.01 $^{NS}$ | 0.21 $^{NS}$ |
| Rainfall | -0.86 $^{NS}$ | -3.00 $^{NS}$ |

**NS**: Non Significant

# Maximum Temperature

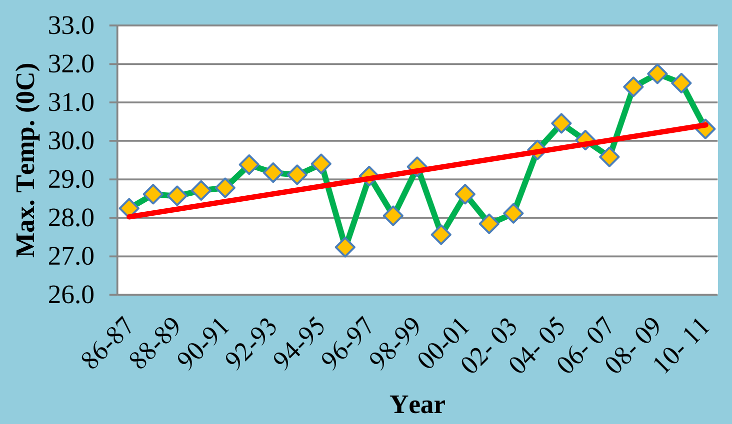


Fig. 1 - Linear trend of Max.temp for the month of Jan.

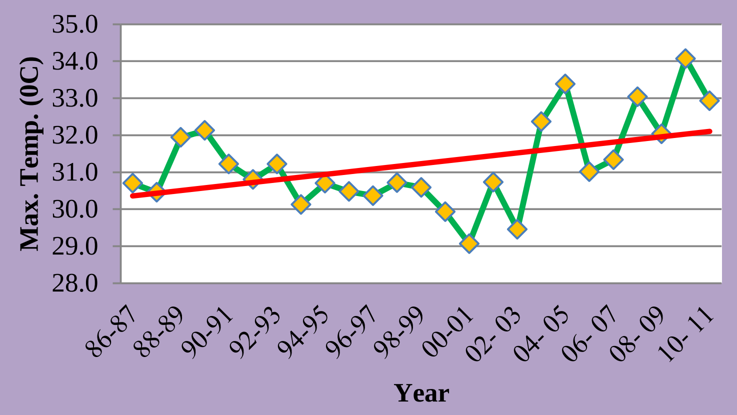


Fig. 2 - Linear trend of Max.temp for the month of Feb.

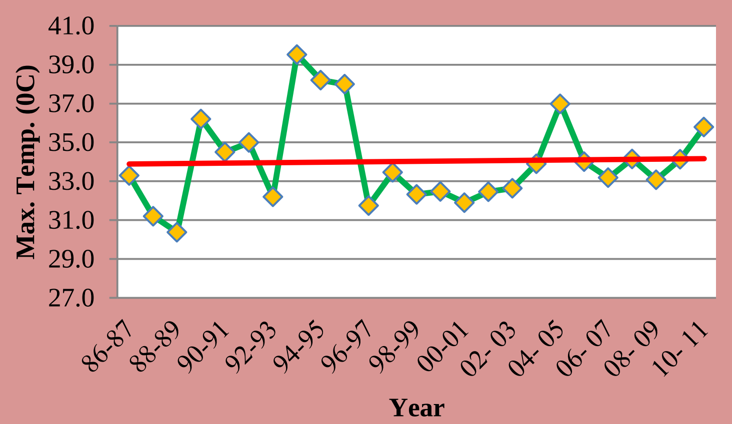


Fig. 3 - Linear trend of Max.temp for the month of Mar.

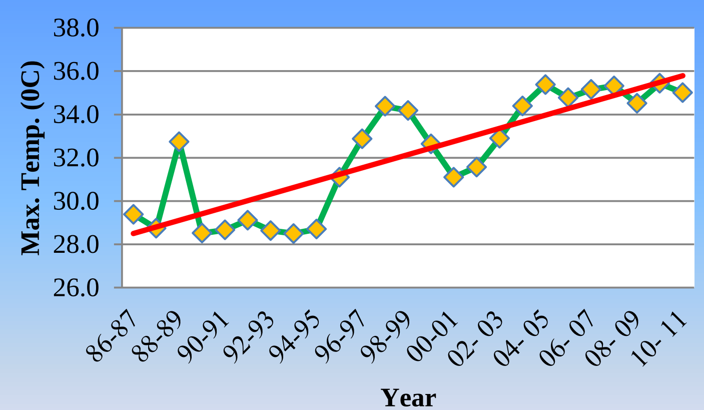


Fig. 4 - Linear trend of Max.temp for the month of Apr.

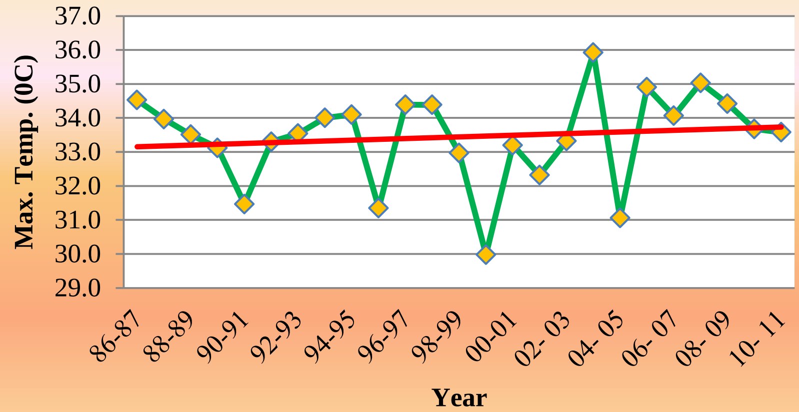


Fig. 5 - Linear trend of Max.temp for the month of May

January

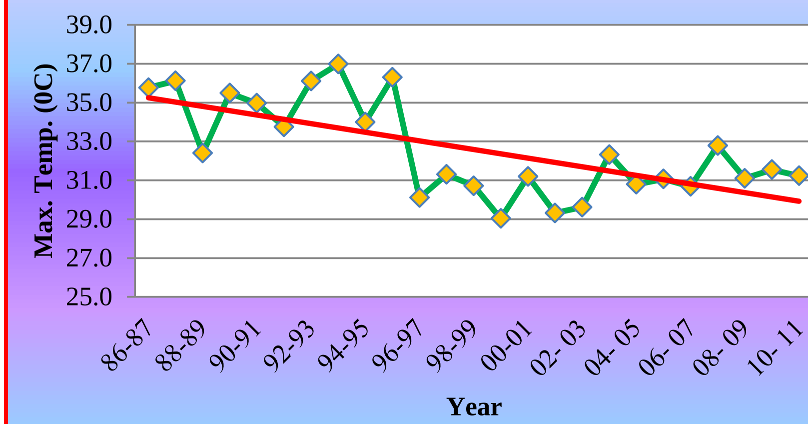


Fig. 6 - Linear trend of Max.temp for the month of Jun.

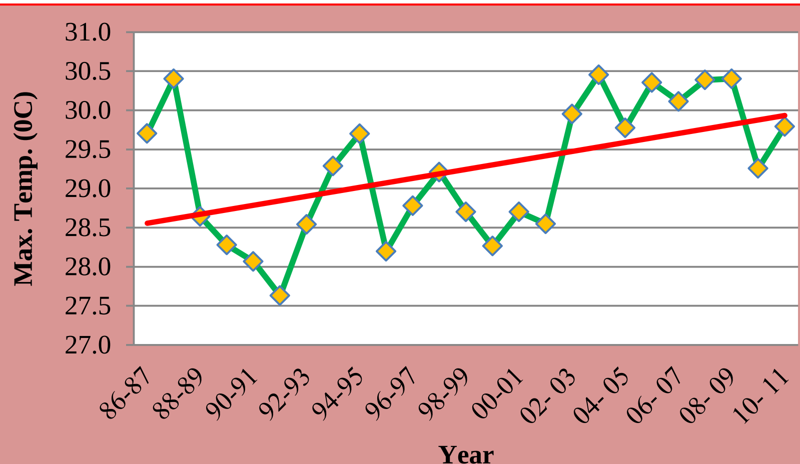


Fig. 7 - Linear trend of Max.temp for the month of Jul.

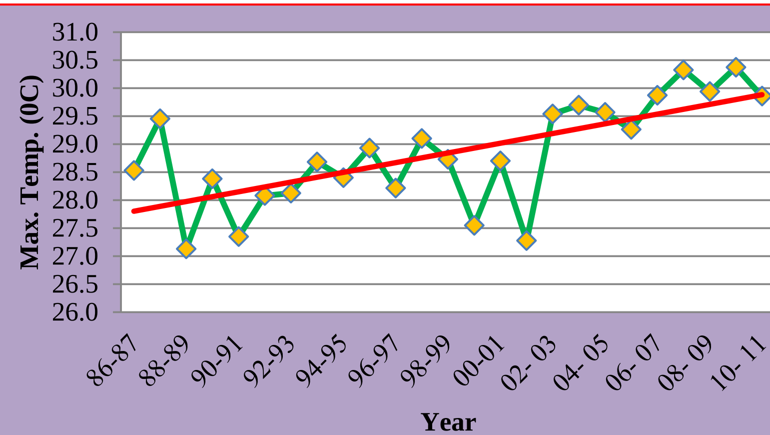


Fig. 8 - Linear trend of Max.temp for the month of Aug.

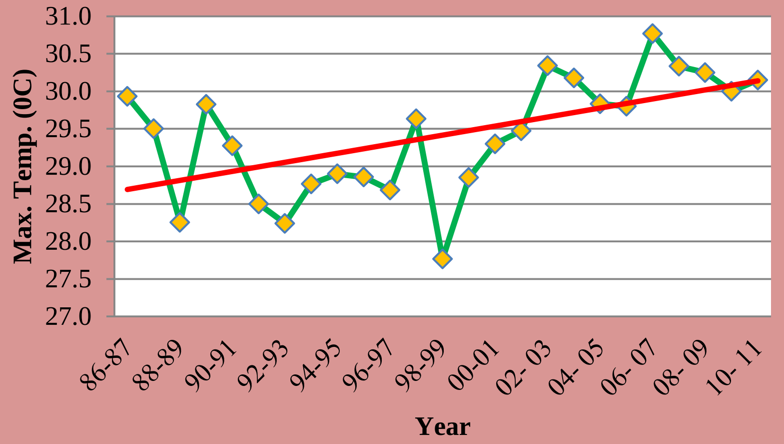


Fig. 9 - Linear trend of Max.temp for the month of Sep.

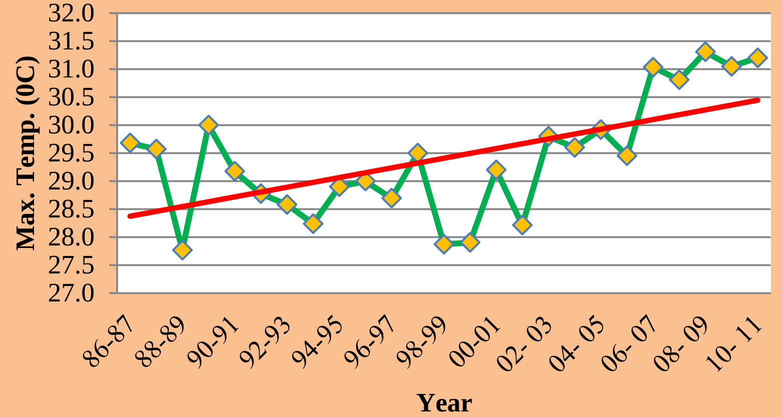


Fig. 10 -Linear trend of Max.temp for the month of Oct.

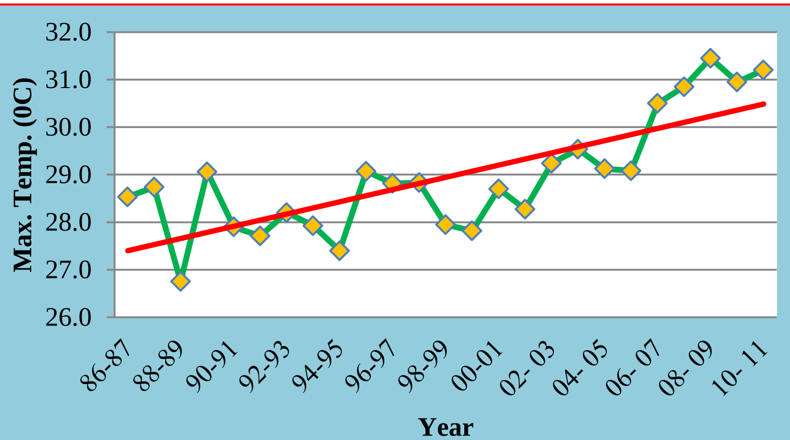


Fig. 11 - Linear trend of Max.temp for the month of Nov.

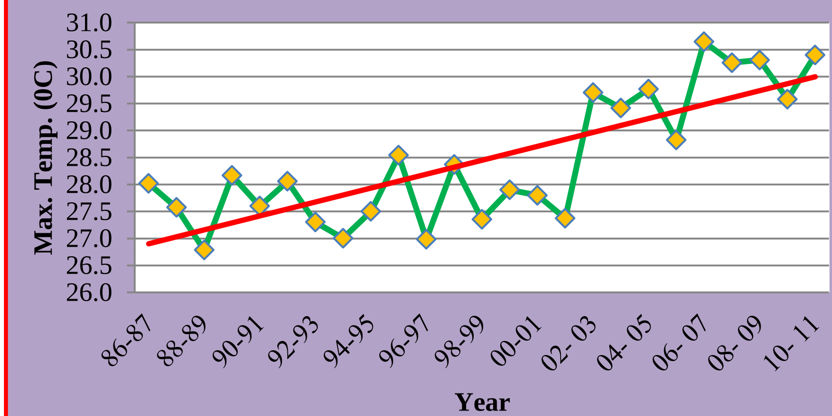


Fig. 12 - Linear trend of Max.temp for the month of Dec.

## Minimum Temperature

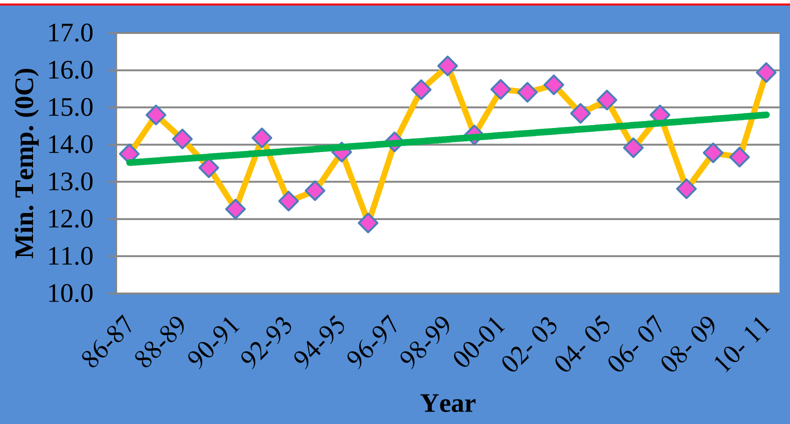


Fig. 13 - Exponential trend of Min.temp for the month of Jan.

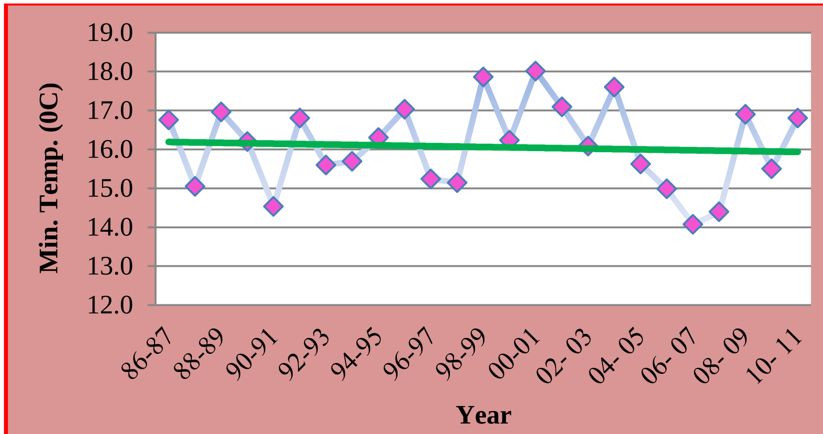


Fig. 14 - Exponential trend of Min.temp for the month of Feb.

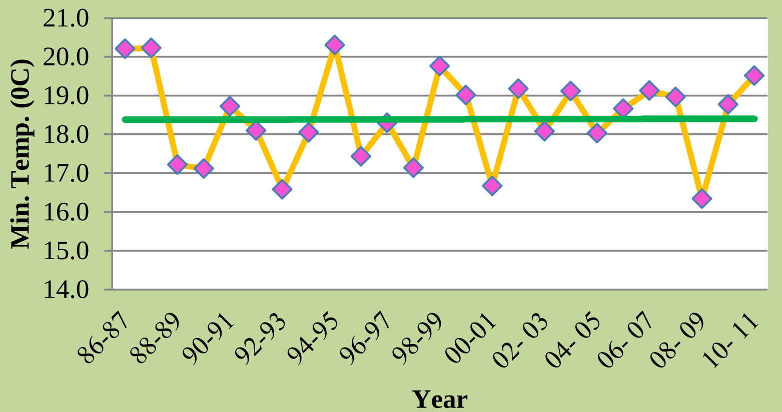


Fig. 15 - Exponential trend of Min.temp for the month of Mar.

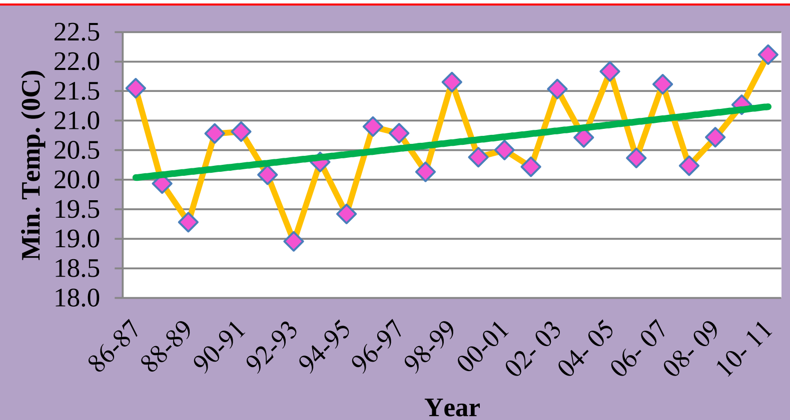


Fig. 16 -Exponential trend of Min.temp for the month of Apr.

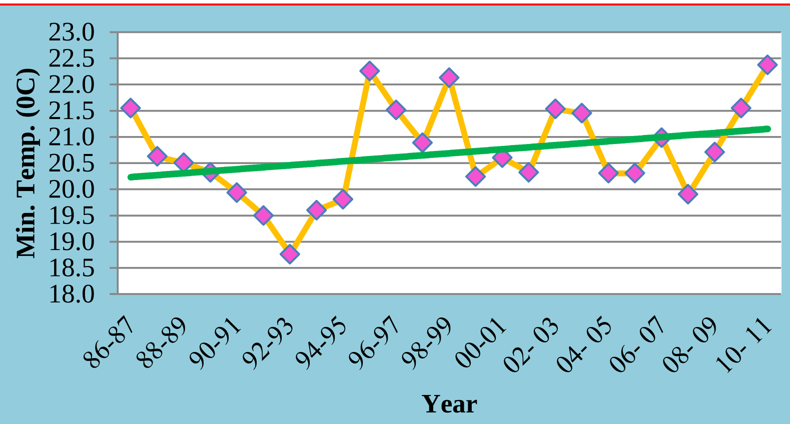


Fig. 17 -Exponential trend of Min.temp for the month of May

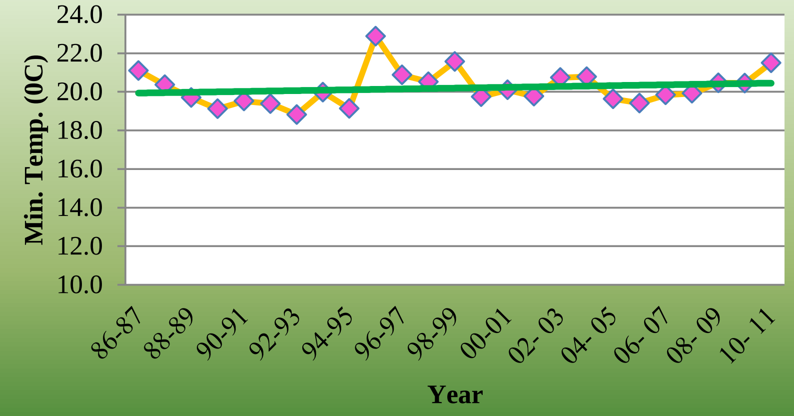


Fig. 18- Exponential trend of Min.temp for the month of Jun.

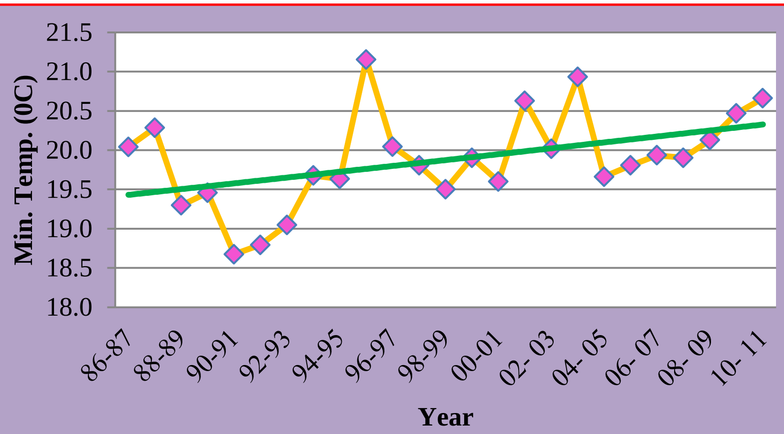


Fig. 19 - Exponential trend of Min.temp for the month of Jul.

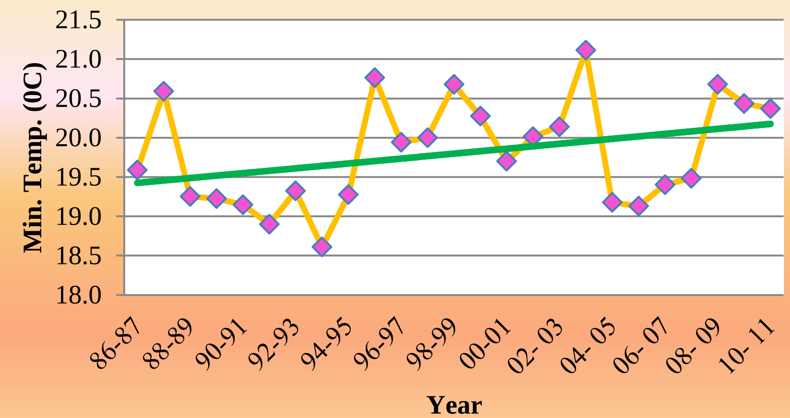


Fig. 20 - Exponential trend of Min.temp for the month of Aug.

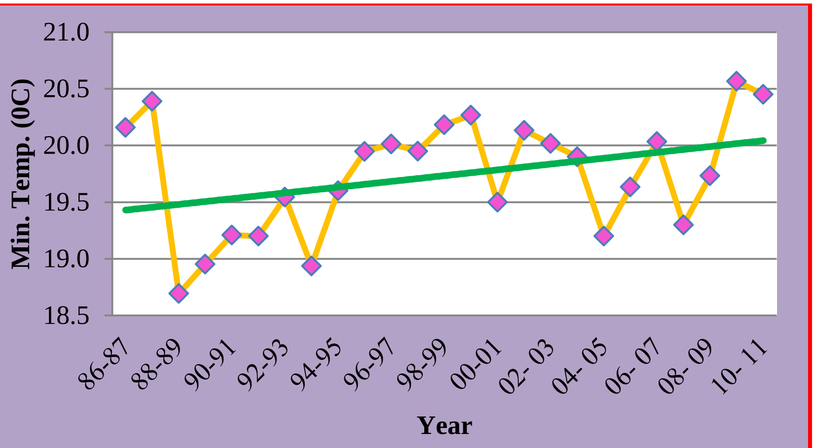


Fig. 21 - Exponential trend of Min.temp for the month of Sep.

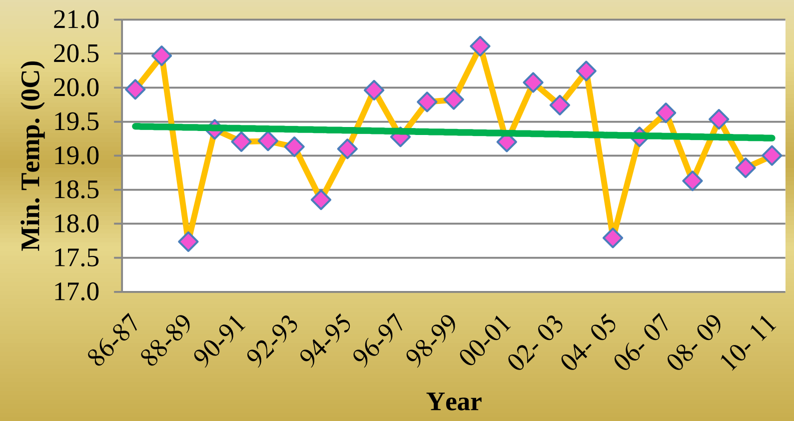


Fig. 22 - Exponential trend of Min.temp for the month of Oct.

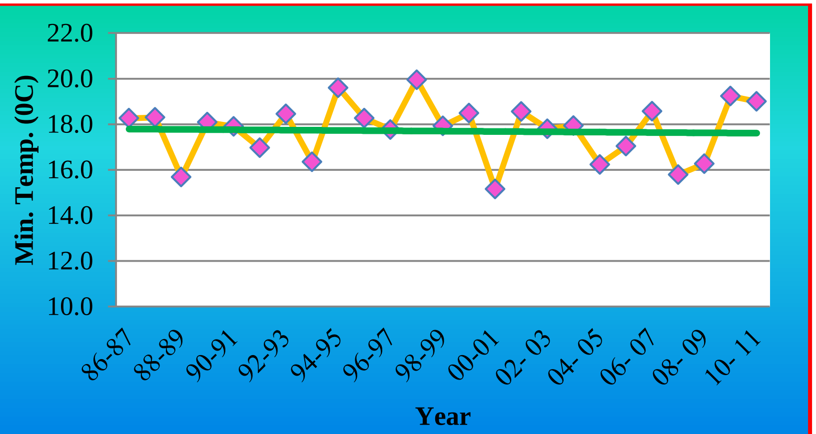


Fig. 23-Exponential trend of Min.temp for the month of Nov.

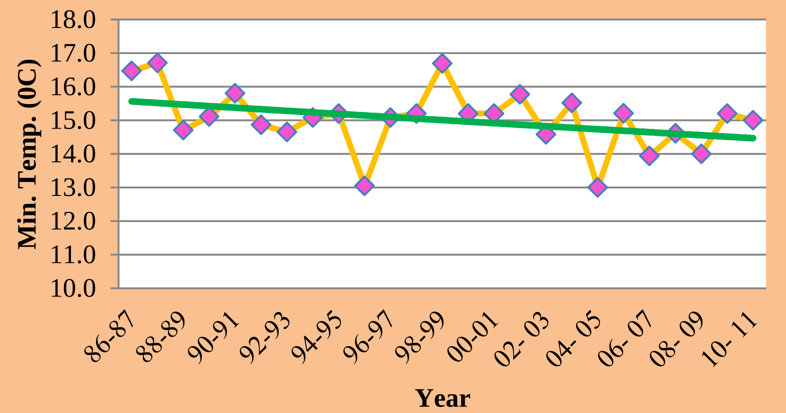


Fig. 24- Exponential trend of Min.temp for the month of Dec.

#### 4.1.2.2 Test for Normality test

**Shapiro-Wilk test and Anderson-Darling test**

In order to test the normality of the error terms the test statistic derived by Shapiro-Wilk test (W) and Anderson-Darling test ($A^2$) made use, the results are presented in the Table 4.1.2.2. It was found that the error term follows the normality.

**Table- 4.1.2.2 Results of test of normality**

| Parameters | 1991-2000 | | 2000-2010 | |
|---|---|---|---|---|
| | **W** | **$A^2$** | **W** | **$A^2$** |
| Max. temp | $0.950^{NS}$ | $0.473^{NS}$ | $0.914^{NS}$ | $0.372^{NS}$ |
| Min. temp | $0.979^{NS}$ | $0.231^{NS}$ | $0.987^{NS}$ | $0.212^{NS}$ |
| Relative humidity | $0.978^{NS}$ | $0.277^{NS}$ | $0.931^{NS}$ | $0.455^{NS}$ |
| Cloudiness | $0.961^{NS}$ | $0.399^{NS}$ | $0.968^{NS}$ | $0.294^{NS}$ |
| Wind speed | $0.972^{NS}$ | $0.311^{NS}$ | $0.916^{NS}$ | $0.370^{NS}$ |
| Sun shine hour | $0.920^{NS}$ | $0.314^{NS}$ | $0.952^{NS}$ | $0.413^{NS}$ |
| Rainfall | $0.986^{NS}$ | $0.224^{NS}$ | $0.945^{NS}$ | $0.304^{NS}$ |

**NS**: Non Significant

### 4.1.3 Trend Analysis

Trend analysis was carried out to measure the trend pattern in weather parameters at Mandya district for the period 1986-2010. The trend for selected weather parameters was found by fitting regression equations viz., Linear, Exponential and Logarithmic equations for monthly data and results are presented in the Table 4.1.3.1 to 4.1.3.7 and comparison was done between Linear, Exponential and Logarithmic models in order to ascertain the best fit.

It was found that the maximum temperature has shown a significant trend over a period of time for all the months except March and May in Linear, Exponential and Logarithmic models (Table 4.1.3.1). Further it was found to be non significant in Logarithmic model during Feb, July, September and October months. All months shows positive trend except June which shows negative trend. The linear model was found to be best model to fit trend for maximum temperature as compared to exponential and logarithmic model based on $R^2$ values (Fig.1 to Fig.12).

The minimum temperature shows a non significant trend over a period of time for all the months except April and July in Linear and Exponential model (Table 4.1.3.2). However these months were found to be significant. Most of the months shows negative trend except January and March to August, however these months shows positive trend. The exponential model was found to be best model to fit trend for minimum temperature as compared to Linear and logarithmic model based on $R^2$ values (Fig.13 to Fig.24).

**Table 4.1.3.1: Fitted regression equations for maximum temperature during the period 1986 to 2010**

| Month | Linear (b) | $R^2$ Value | Exponential (b) | $R^2$ Value | Logarithmic (b) | $R^2$ Value |
|---|---|---|---|---|---|---|
| JAN | 0.099** | 0.379 | 0.003** | 0.370 | 0.671* | 0.222 |
| FEB | 0.072* | 0.189 | 0.002* | 0.181 | 0.395NS | 0.171 |
| MAR | 0.010NS | 0.101 | 0.000NS | 0.102 | 0.320NS | 0.113 |
| APR | 0.303** | 0.701 | 0.009** | 0.695 | 2.342** | 0.537 |
| MAY | 0.024NS | 0.117 | 0.000NS | 0.115 | 0.010NS | 0.121 |
| JUN | -0.222** | 0.441 | -0.000** | 0.434 | -1.970** | 0.446 |
| JUL | 0.057* | 0.237 | 0.002* | 0.237 | 0.279NS | 0.172 |
| AUG | 0.086** | 0.454 | 0.003** | 0.447 | 0.566* | 0.248 |
| SEP | 0.060** | 0.322 | 0.002** | 0.317 | 0.316NS | 0.114 |
| OCT | 0.086** | 0.356 | 0.002** | 0.348 | 0.460NS | 0.129 |
| NOV | 0.128** | 0.591 | 0.004** | 0.587 | 0.839** | 0.323 |
| DEC | 0.129** | 0.613 | 0.004** | 0.610 | 0.874** | 0.362 |

****** Significant at 1% level, ***** Significant at 5% level, NS: Non Significant

**Table 4.1.3.2: Fitted regression equations for minimum temperature during the period 1986 to 2010**

| Month | Linear (b) | $R^2$ Value | Exponential (b) | $R^2$ Value | Logarithmic (b) | $R^2$ Value |
|---|---|---|---|---|---|---|
| JAN | 0.053NS | 0.111 | 0.003NS | 0.109 | 0.402NS | 0.081 |
| FEB | -0.009NS | 0.104 | -0.001NS | 0.005 | -0.040NS | 0.001 |
| MAR | -0.000NS | 0.112 | 0.001NS | 0.016 | -0.190NS | 0.019 |
| APR | 0.049 * | 0.207 | 0.002* | 0.207 | 0.289NS | 0.089 |
| MAY | 0.038NS | 0.094 | 0.001NS | 0.095 | 0.194NS | 0.031 |
| JUN | 0.020NS | 0.028 | 0.001NS | 0.031 | 0.104NS | 0.009 |
| JUL | 0.037 * | 0.202 | 0.001* | 0.206 | 0.237NS | 0.107 |
| AUG | 0.031NS | 0.115 | 0.001NS | 0.116 | 0.218NS | 0.073 |
| SEP | 0.025NS | 0.131 | 0.001NS | 0.132 | 0.142NS | 0.053 |
| OCT | -0.004NS | 0.002 | -0.002NS | 0.001 | -0.050NS | 0.004 |
| NOV | -0.020NS | 0.013 | -0.000NS | 0.015 | -0.120NS | 0.006 |
| DEC | -0.046NS | 0.137 | -0.000NS | 0.130 | -0.480NS | 0.194 |

* Significant at 5% level, NS: Non Significant

## Relative humidity

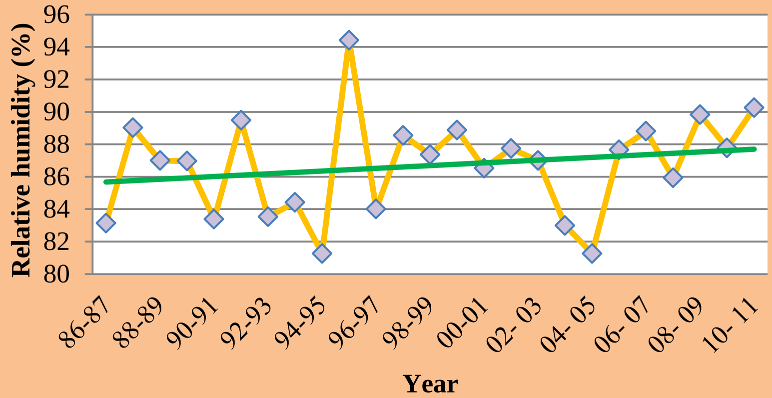


Fig. 25- Linear trend of relative humidity for the month of Jan.

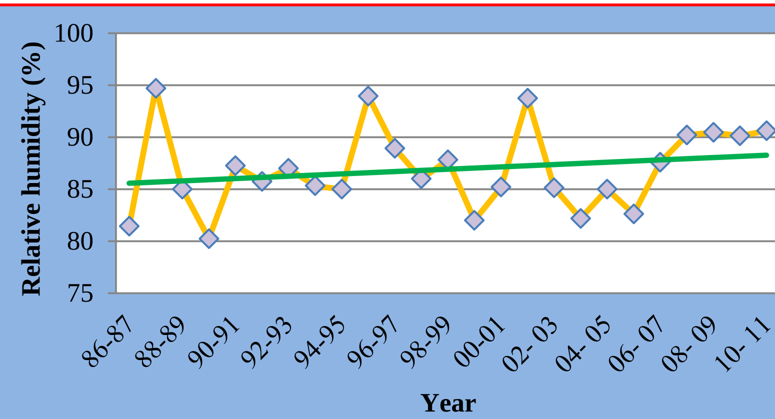


Fig. 26- Linear trend of relative humidity for the month of Feb.

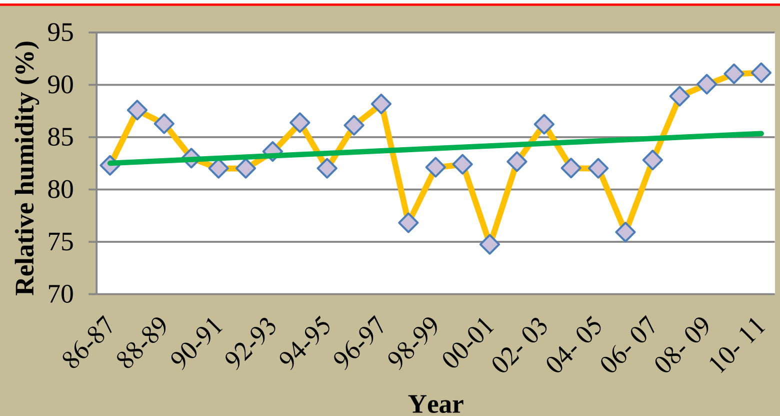


Fig. 27 -Linear trend of relative humidity for the month of Mar.

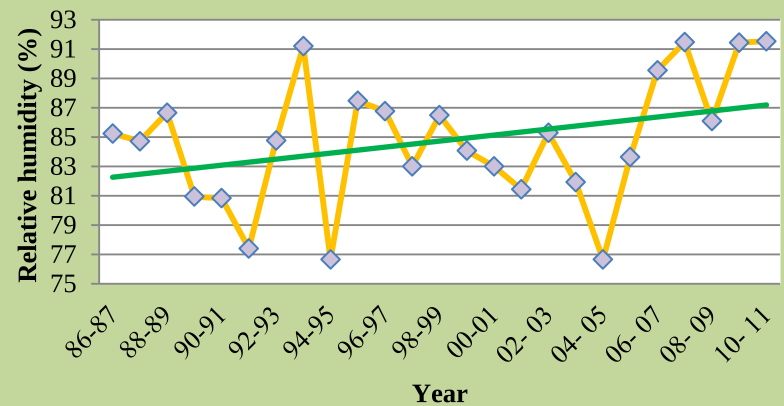


Fig. 28 - Linear trend of relative humidity for the month of Apr.

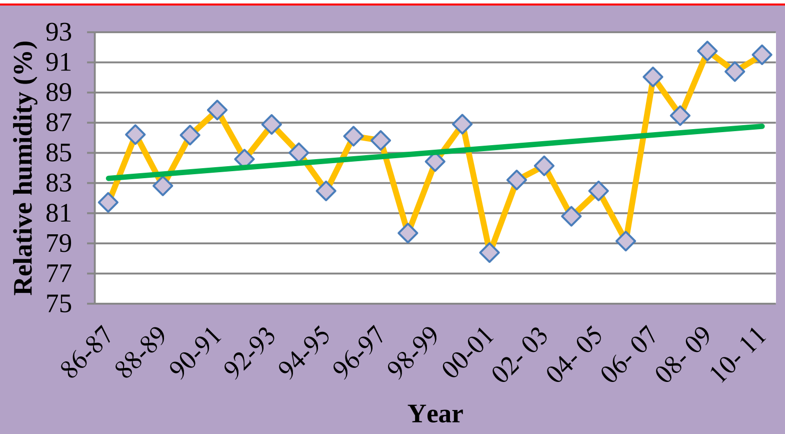


**Fig.29 - Linear trend of relative humidity for the month of May**

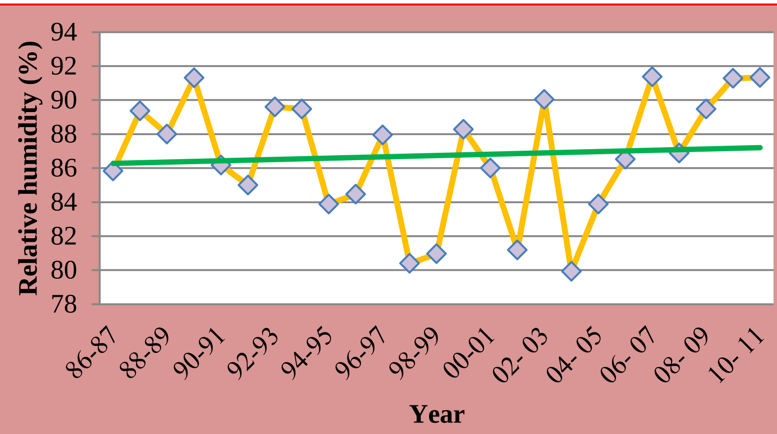


**Fig.30 - Linear trend of relative humidity for the month of Jun.**

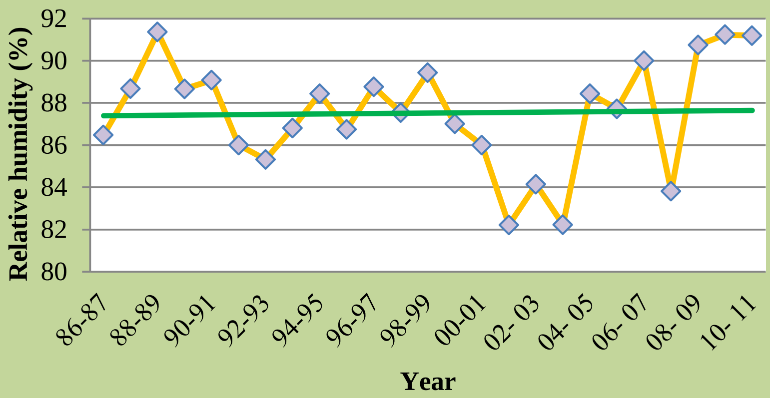


**Fig.31 - Linear trend of relative humidity for the month of Jul.**

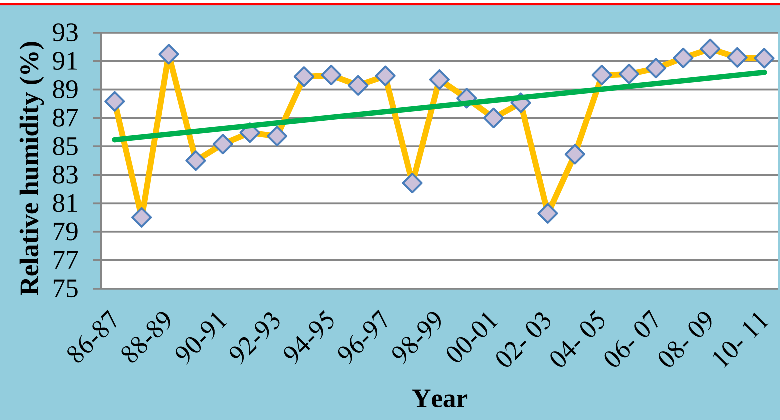


**Fig.32 - Linear trend of relative humidity for the month of Aug.**

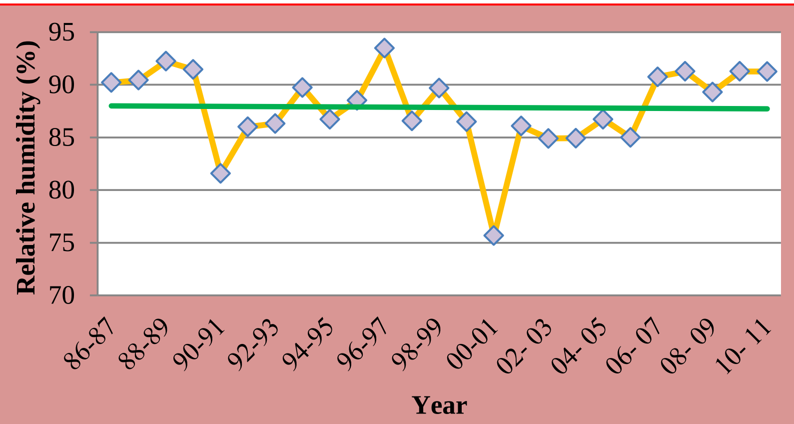


**Fig. 33 -Linear trend of relative humidity for the month of sep.**

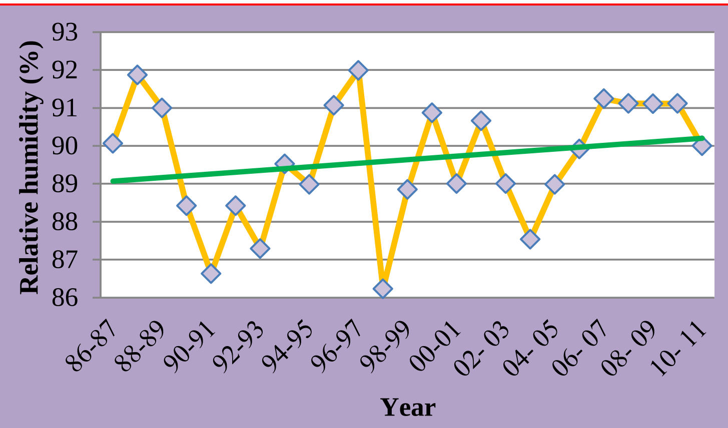


**Fig. 34 -Linear trend of relative humidity for the month of Oct.**

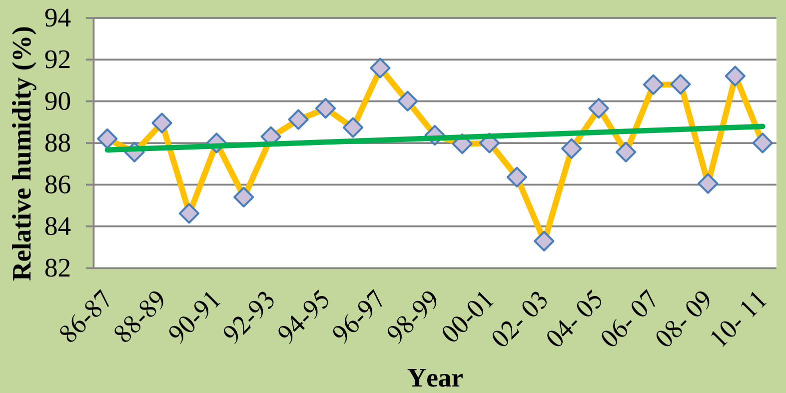


**Fig. 35 -Linear trend of relative humidity for the month of Nov.**

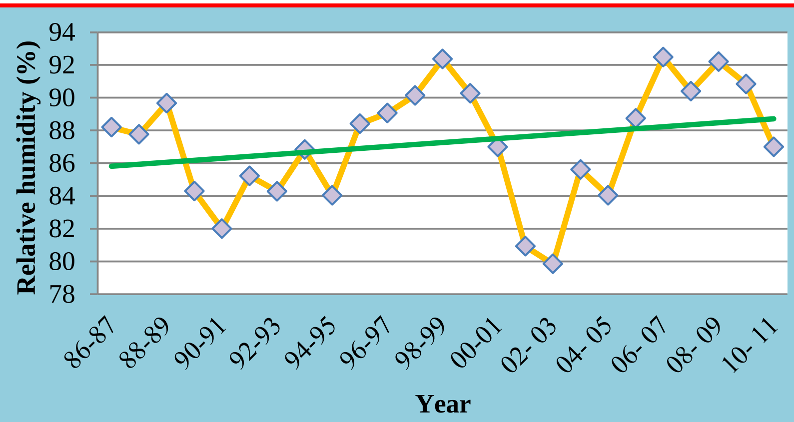


**Fig. 36 - Linear trend of relative humidity for the month of Dec.**

## Cloudiness

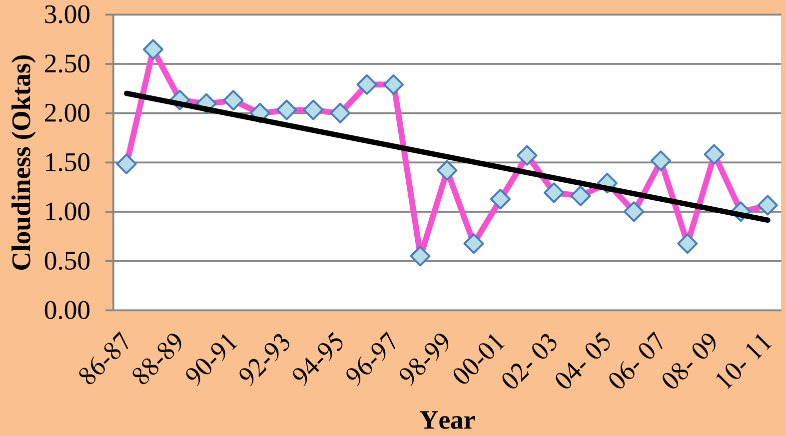


**Fig. 37 - Linear trend of cloudiness for the month of Jan.**

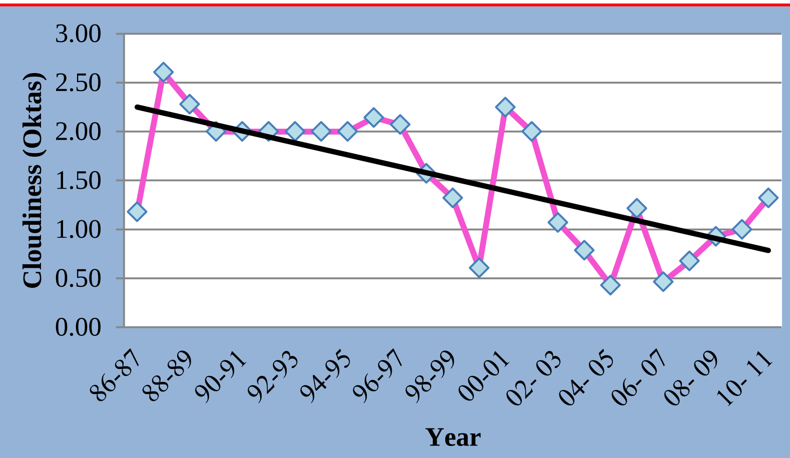


**Fig. 38 -Linear trend of cloudiness for the month of Feb.**

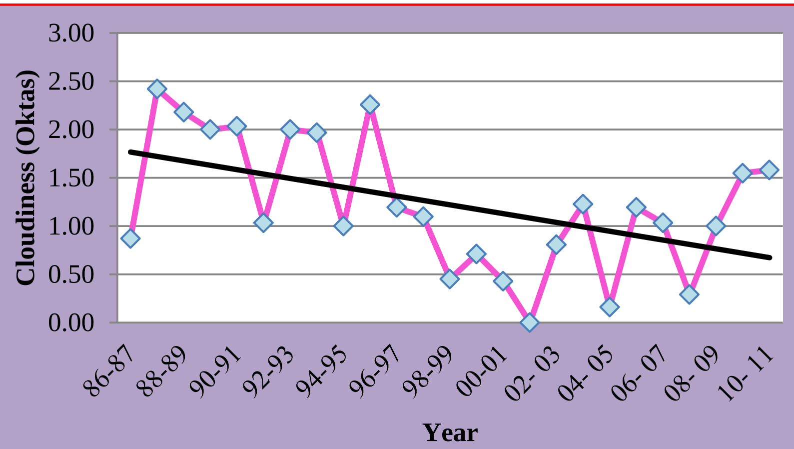


**Fig. 39 - Linear trend of cloudiness for the month of Mar.**

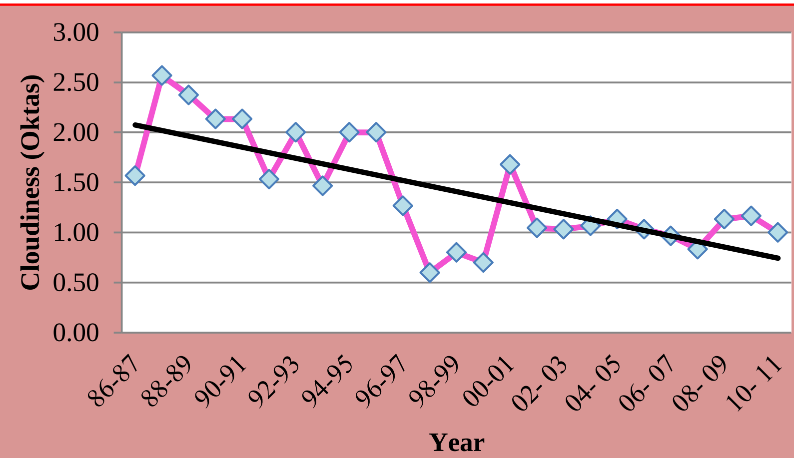


**Fig. 40 - Linear trend of cloudiness for the month of Apr.**

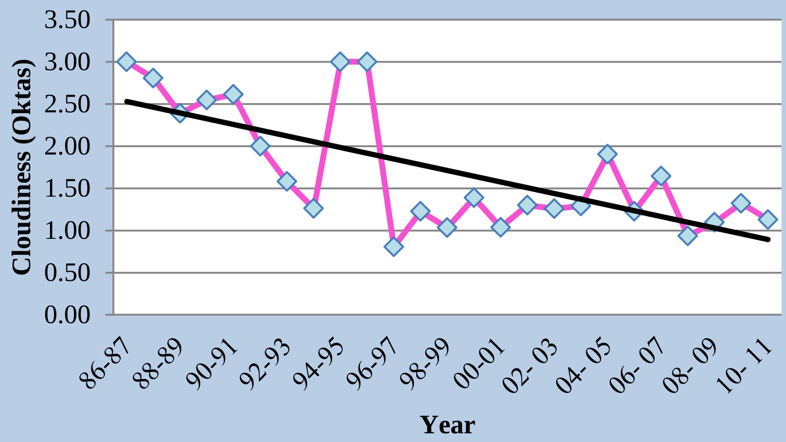


Fig. 41- Linear trend of cloudiness for the month of May

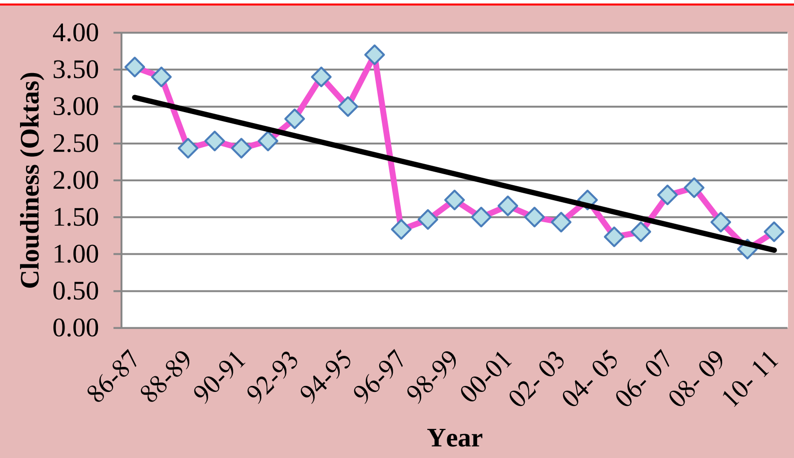


Fig. 42-Linear trend of cloudiness for the month of Jun.

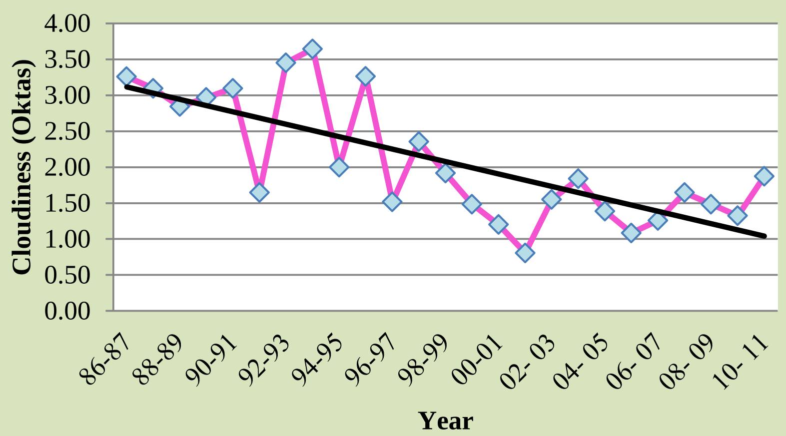


Fig. 43 - Linear trend of cloudiness for the month of Jul.

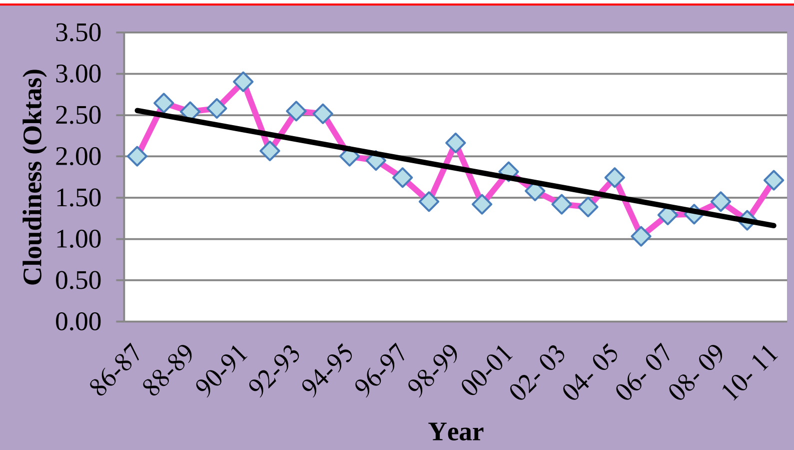


Fig. 44 - Linear trend of cloudiness for the month of Aug.

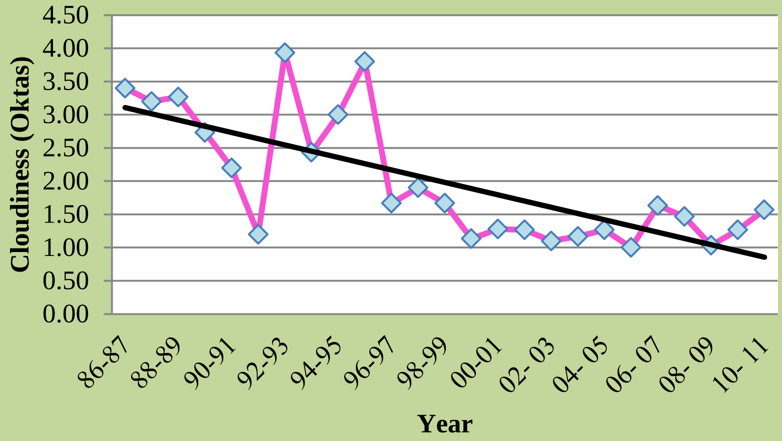


**Fig.45 - Linear trend of cloudiness for the month of Sep.**

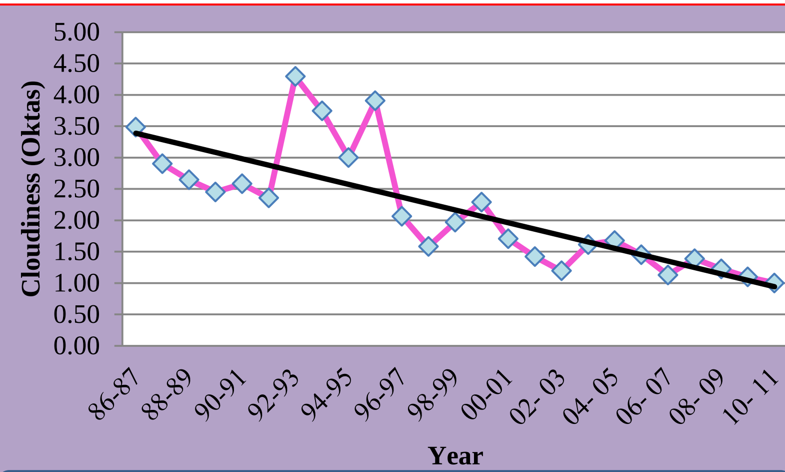


**Fig.46 - Linear trend of cloudiness for the month of Oct.**

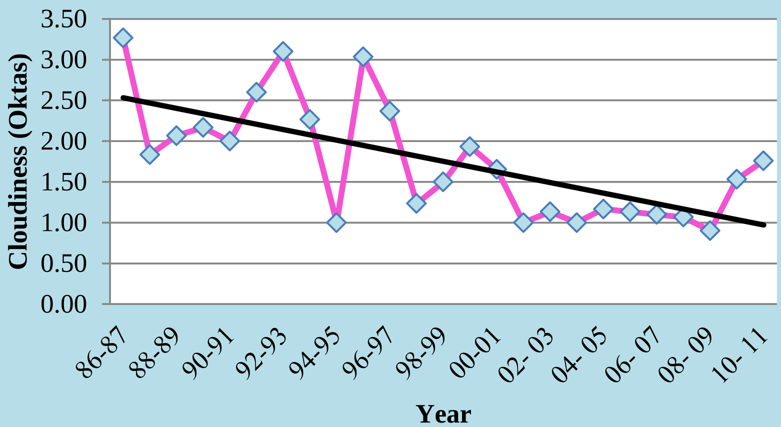


**Fig.47 - Linear trend of cloudiness for the month of Nov.**

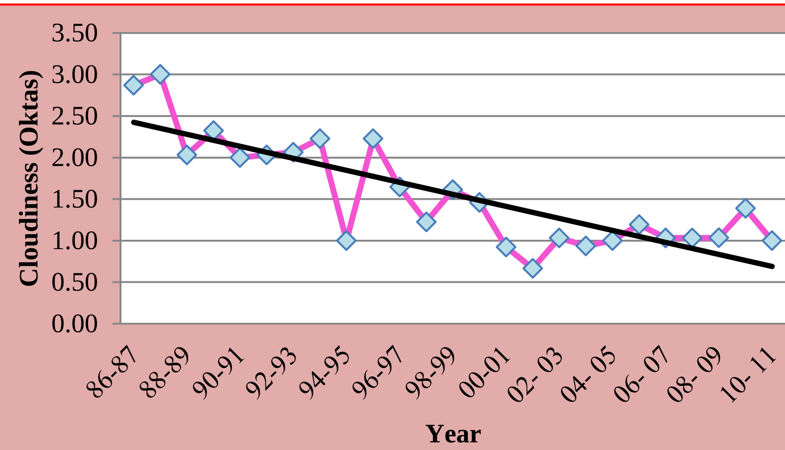


**Fig.48 -Linear trend of cloudiness for the month of Dec.**

Wind speed

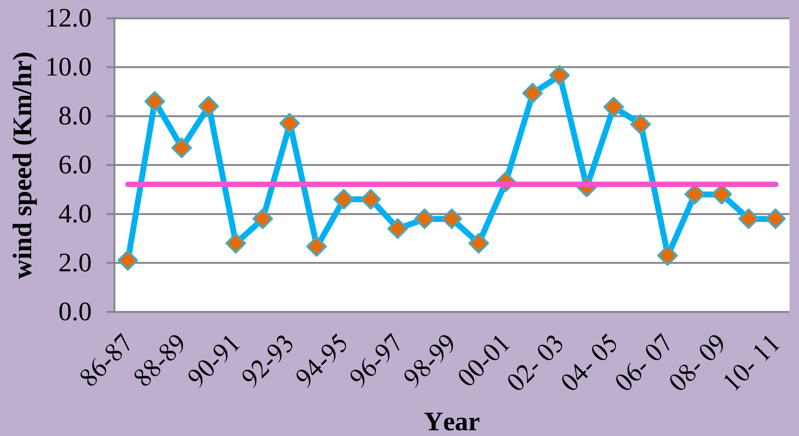


Fig. 49 -Logarithmic trend of wind speed for the month of Jan.

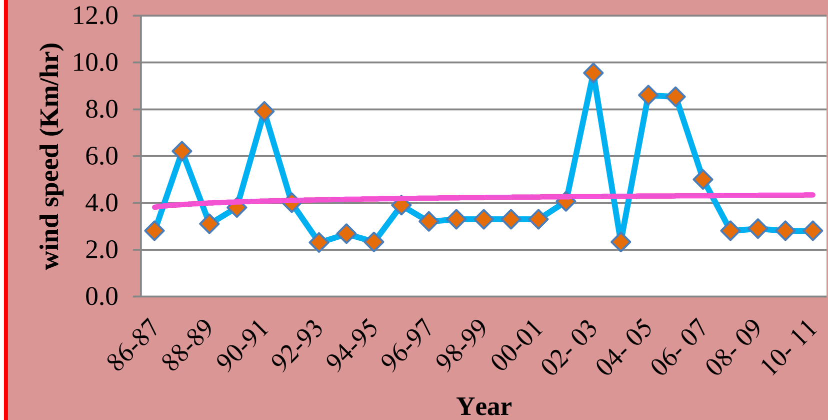


Fig. 50 -Logarithmic trend of wind speed for the month of Feb.

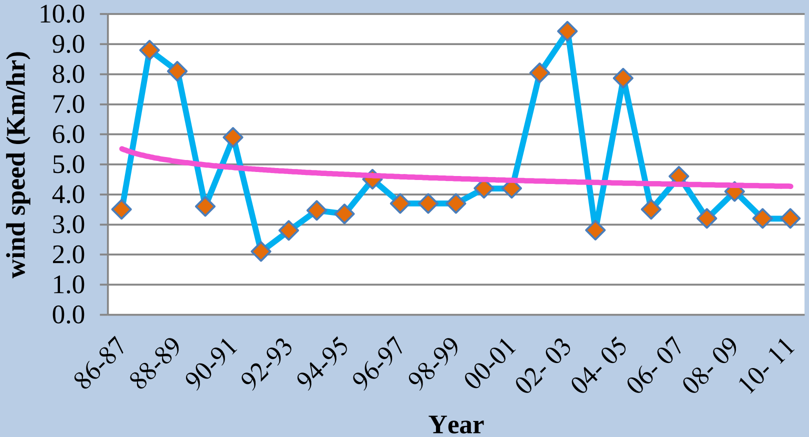


Fig. 51 - Logarithmic trend of wind speed for the month of Mar.

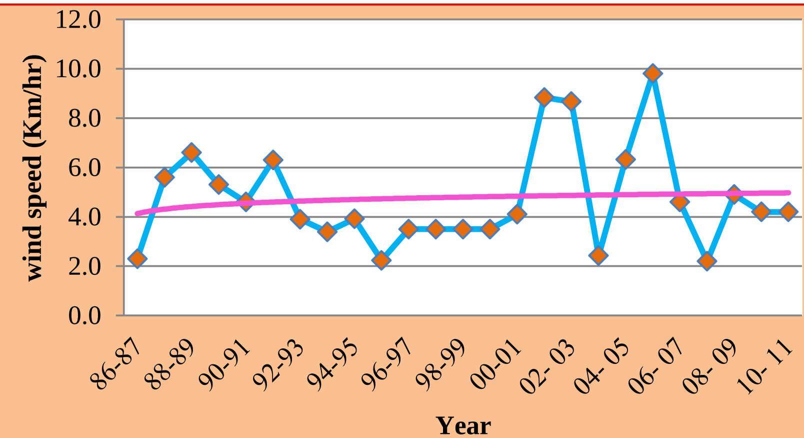


Fig. 52 - Logarithmic trend of wind speed for the month of Apr.

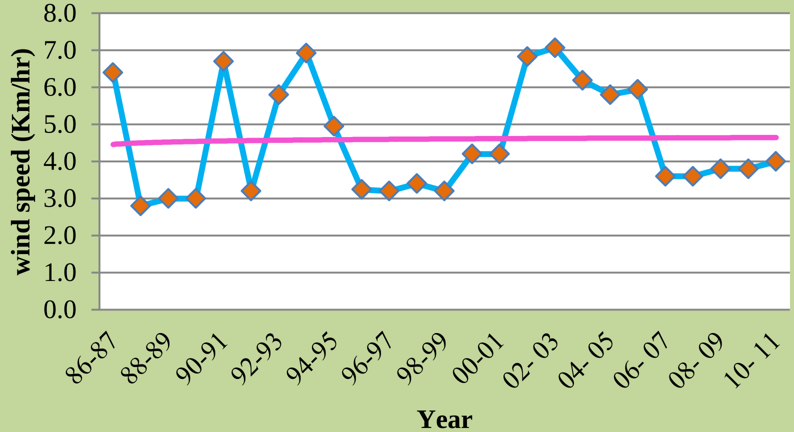


**Fig. 53 -Logarithmic trend of wind speed for the month of May**

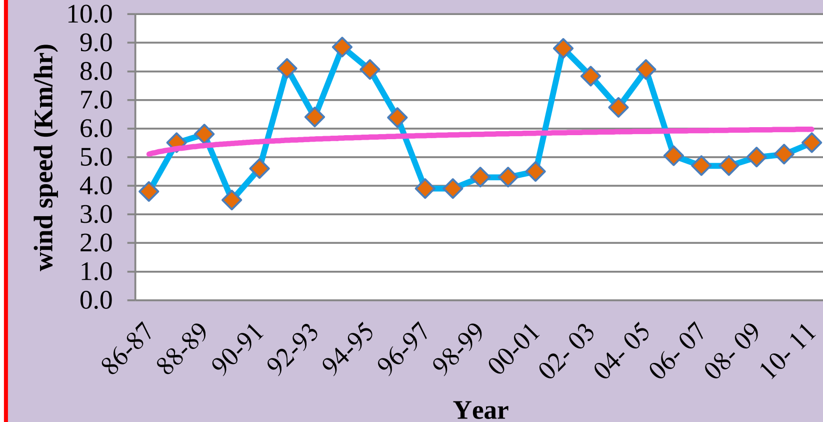


**Fig. 54 -Logarithmic trend of wind speed for the month of Jun.**

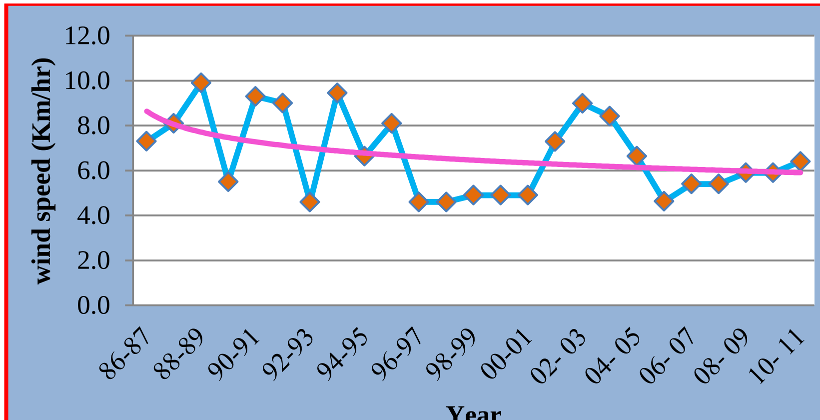


**Fig. 55 -Logarithmic trend of wind speed for the month of Jul.**

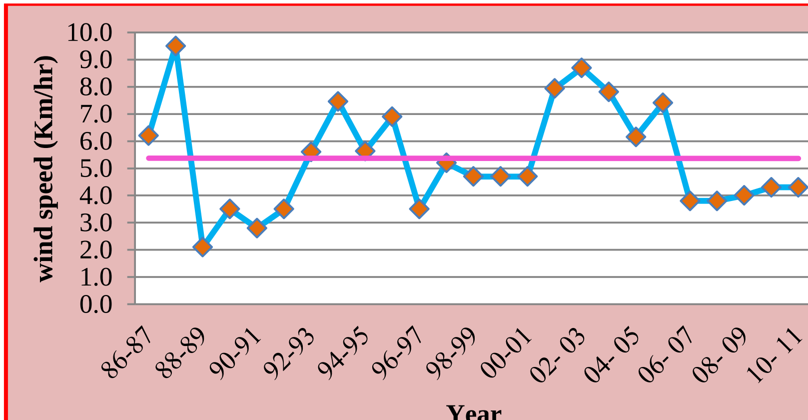


**Fig. 56 -Logarithmic trend of wind speed for the month of Aug.**

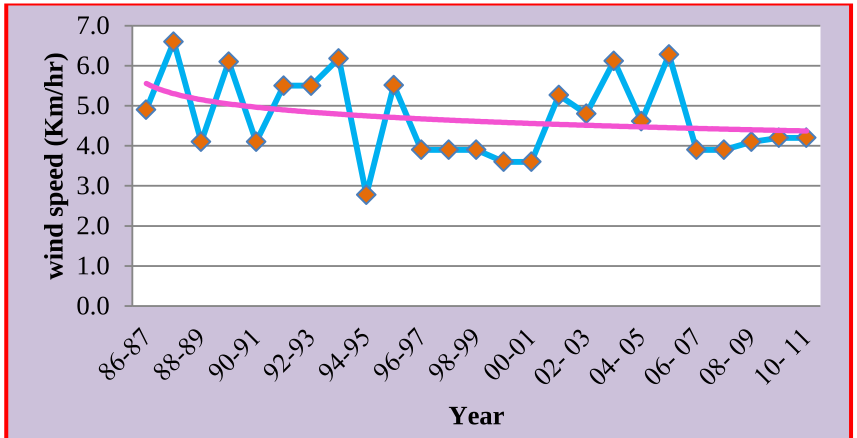


**Fig. 57-Logarithmic trend of wind speed for the month of Sep.**

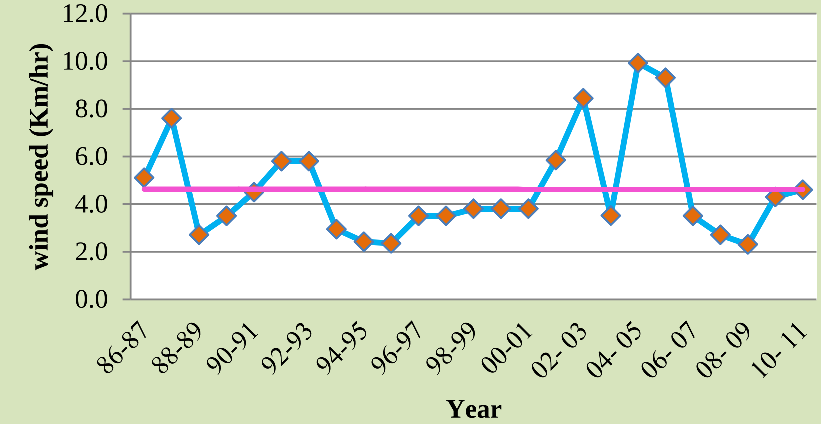


**Fig. 58 -Logarithmic trend of wind speed for the month of Oct.**

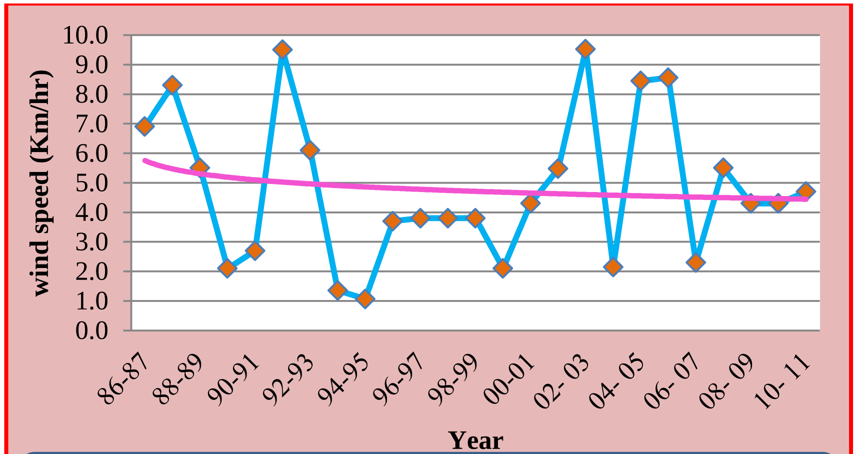


**Fig. 59-Logarithmic trend of wind speed for the month of Nov.**

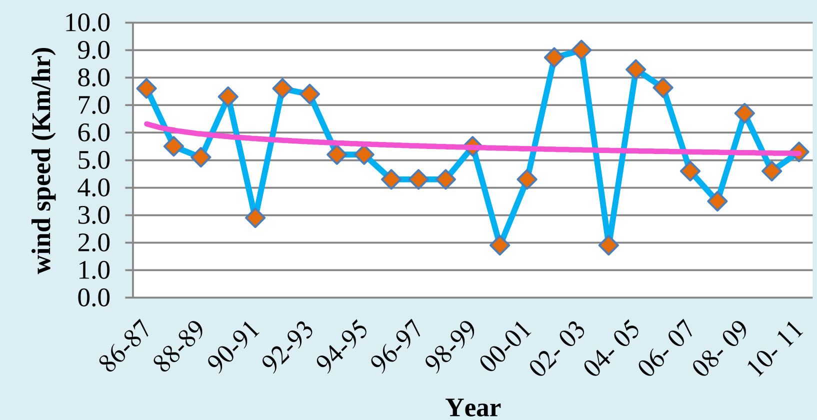


**Fig. 60 -Logarithmic trend of wind speed for the month of Dec.**

## Sun shine hour

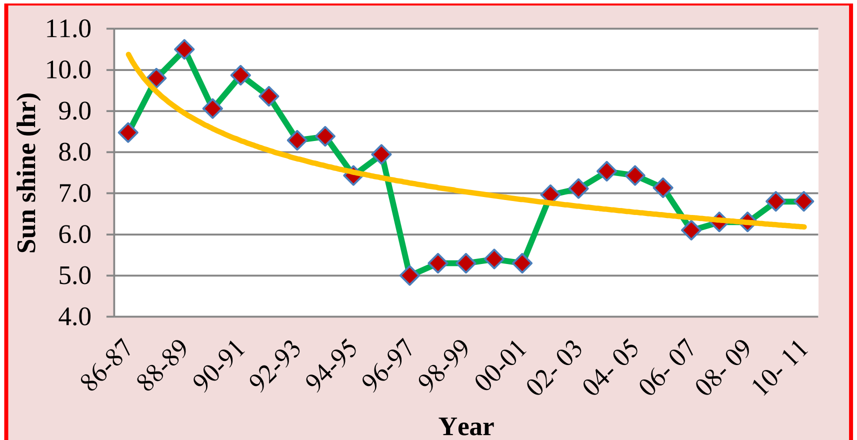


Fig.61-Logarithmic trend of sun shine hour for the month of Jan.

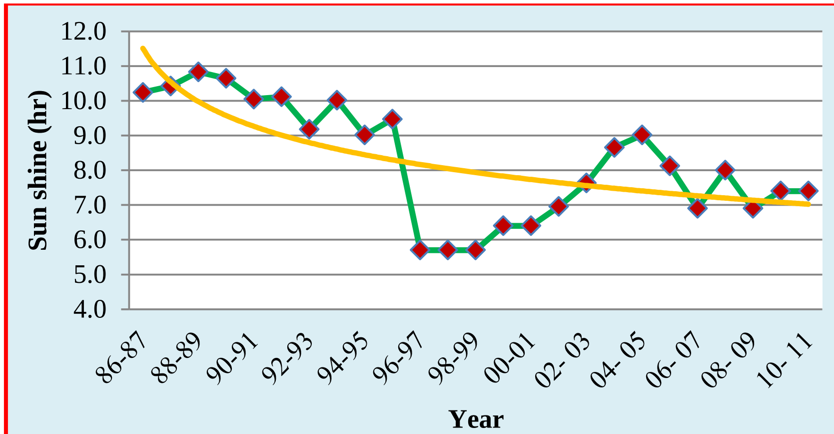


Fig.62 -Logarithmic trend of sun shine hour for the month of Feb.

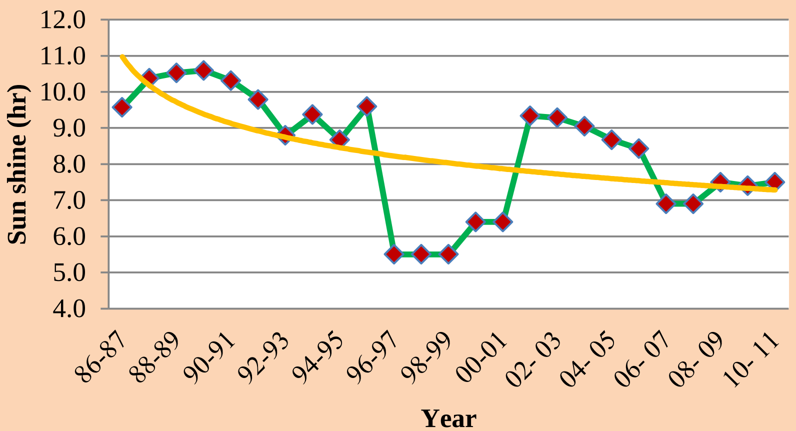


Fig.63 -Logarithmic trend of sun shine hour for the month of Mar.

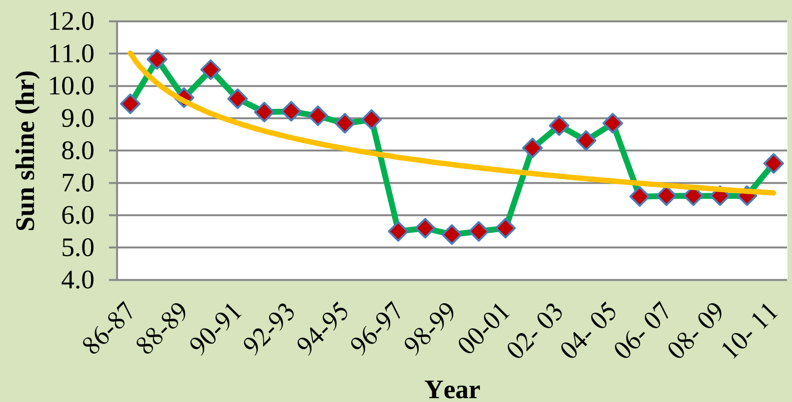


Fig.64 -Logarithmic trend of sun shine hour for the month of Apr.

It was found that, the relative humidity shown a non significant trend during study period for all the months except August in Linear and Exponential model (Table 4.1.3.3). However this month was found to be significant. All the months shows positive trend except September in Linear and Exponential model and June, July, and September in Logarithmic model. These months shows negative trend. The linear model was found to be best model to fit trend for Relative humidity as compared to exponential and logarithmic model based on $R^2$ values (Fig.25 to Fig.36).

**Table 4.1.3.3: Fitted regression equations for relative humidity during the period 1986 to 2010**

| Month | Linear (b) | $R^2$ Value | Exponential (b) | $R^2$ Value | Logarithmic (b) | $R^2$ Value |
|---|---|---|---|---|---|---|
| JAN | 0.083$^{NS}$ | 0.039 | 0.001$^{NS}$ | 0.040 | 0.677$^{NS}$ | 0.033 |
| FEB | 0.112$^{NS}$ | 0.044 | 0.001$^{NS}$ | 0.047 | 0.890$^{NS}$ | 0.035 |
| MAR | 0.117$^{NS}$ | 0.040 | 0.001$^{NS}$ | 0.033 | 0.369$^{NS}$ | 0.005 |
| APR | 0.205$^{NS}$ | 0.118 | 0.002$^{NS}$ | 0.112 | 1.110$^{NS}$ | 0.044 |
| MAY | 0.143$^{NS}$ | 0.082 | 0.001$^{NS}$ | 0.074 | 0.864$^{NS}$ | 0.038 |
| JUN | 0.036$^{NS}$ | 0.005 | 0.000$^{NS}$ | 0.004 | -0.210 $^{NS}$ | 0.002 |
| JUL | 0.010$^{NS}$ | 0.000 | 0.002$^{NS}$ | 0.005 | -0.190$^{NS}$ | 0.003 |
| AUG | 0.197$^{*}$ | 0.174 | 0.002 $^{*}$ | 0.169 | 1.467$^{NS}$ | 0.124 |
| SEP | -0.011$^{NS}$ | 0.000 | -0.001$^{NS}$ | 0.003 | -0.710$^{NS}$ | 0.023 |
| OCT | 0.047$^{NS}$ | 0.046 | 0.000$^{NS}$ | 0.047 | 0.118$^{NS}$ | 0.003 |
| NOV | 0.047$^{NS}$ | 0.029 | 0.000$^{NS}$ | 0.028 | 0.388$^{NS}$ | 0.025 |
| DEC | 0.121$^{NS}$ | 0.063 | 0.001$^{NS}$ | 0.059 | 0.624$^{NS}$ | 0.021 |

***** Significant at 5% level, NS: Non Significant

It was found that the Cloudiness shown a negative significant trend during study period for all the months in Linear, Exponential and Logarithmic model (Table 4.1.3.4). The linear model was found to be best model to fit trend for cloudiness as compared to exponential and logarithmic model based on $R^2$ values (Fig.37 to Fig.48).

It was observed that the wind speed shown a non significant trend during study period for all the months in Linear, Exponential and Logarithmic model (Table 4.1.3.5). All the months shown negative trend except February, April, May, June and October, these months shows positive trend. The logarithmic model was found to be best model to fit trend for wind speed as compared to Linear and exponential model based on $R^2$ values (Fig.49 to Fig.60).

**Table 4.1.3.4: Fitted regression equations for cloudiness during the period 1986 to 2010**

| Month | Linear (b) | $R^2$ Value | Exponential (b) | $R^2$ Value | Logarithmic (b) | $R^2$ Value |
|---|---|---|---|---|---|---|
| JAN | -0.053** | 0.464 | -0.030** | 0.367 | -0.410 ** | 0.359 |
| FEB | -0.061** | 0.480 | -0.040** | 0.423 | -0.420** | 0.303 |
| MAR | -0.045* | 0.234 | NA | - | -0.390* | 0.221 |
| APR | -0.055** | 0.535 | -0.030** | 0.460 | -0.470** | 0.507 |
| MAY | -0.068** | 0.471 | -0.030** | 0.444 | -0.640** | 0.539 |
| JUN | -0.086** | 0.594 | NA | - | -0.740** | 0.575 |
| JUL | -0.086** | 0.553 | -0.040** | 0.518 | -0.740** | 0.529 |
| AUG | -0.058** | 0.666 | -0.030** | 0.666 | -0.450** | 0.534 |
| SEP | -0.093** | 0.531 | -0.040** | 0.552 | -0.820** | 0.521 |
| OCT | -0.101** | 0.619 | -0.050** | 0.732 | -0.780** | 0.474 |
| NOV | -0.065** | 0.447 | -0.030** | 0.455 | -0.560** | 0.432 |
| DEC | -0.072** | 0.673 | NA | - | 0.8740** | 0.362 |

****** Significant at 1% level, ***** Significant at 5% level,

**Table 4.1.3.5: Fitted regression equations for wind speed during the period 1986 to 2010**

| Month | Linear (b) | $R^2$ Value | Exponential (b) | $R^2$ Value | Logarithmic (b) | $R^2$ Value |
|---|---|---|---|---|---|---|
| JAN | -0.007NS | 0.001 | 0.002NS | 0.001 | -0.002NS | 0.002 |
| FEB | 0.020NS | 0.005 | 0.002NS | 0.001 | 0.161NS | 0.004 |
| MAR | -0.035NS | 0.015 | -0.005NS | 0.010 | -0.388NS | 0.024 |
| APR | 0.028NS | 0.010 | 0.004NS | 0.005 | 0.261NS | 0.011 |
| MAY | 0.006 NS | 0.001 | 0.004NS | 0.008 | 0.057NS | 0.001 |
| JUN | 0.004NS | 0.005 | 0.002NS | 0.003 | 0.271 NS | 0.018 |
| JUL | -0.094NS | 0.153 | -0.013NS | 0.128 | -0.851* | 0.159 |
| AUG | -0.001NS | 0.001 | 0.004NS | 0.006 | -0.046NS | 0.001 |
| SEP | -0.038NS | 0.075 | -0.007NS | 0.061 | -0.369NS | 0.089 |
| OCT | 0.020NS | 0.005 | 0.002NS | 0.001 | -0.271NS | 0.043 |
| NOV | -0.004NS | 0.001 | 0.005NS | 0.003 | -0.406NS | 0.018 |
| DEC | -0.021NS | 0.006 | -0.006NS | 0.010 | -0.335NS | 0.019 |

***** Significant at 5% level, NS: Non Significant

It was noticed that the sun shine hour shown a negative significant trend during study period for all the months in Linear, Exponential and Logarithmic model (Table 4.1.3.6). The logarithmic model was found to be best model to fit trend for Sun Shine hour as compared to Linear and exponential model based on $R^2$ values (Fig.61 to Fig.72).

## Sun shine hour

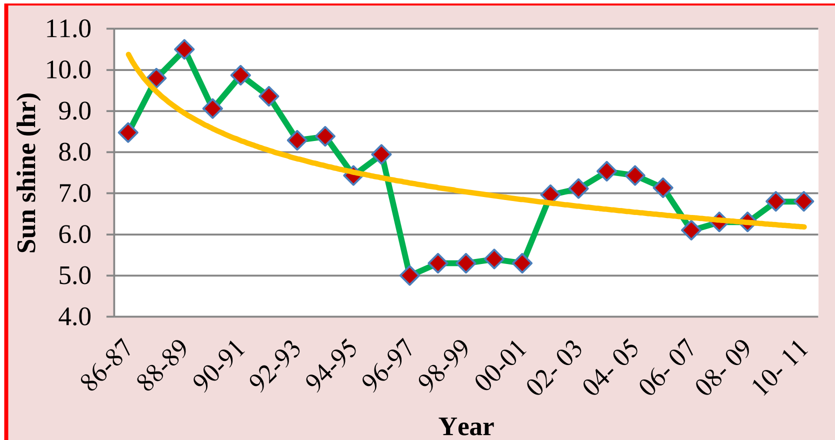


Fig.61-Logarithmic trend of sun shine hour for the month of Jan.

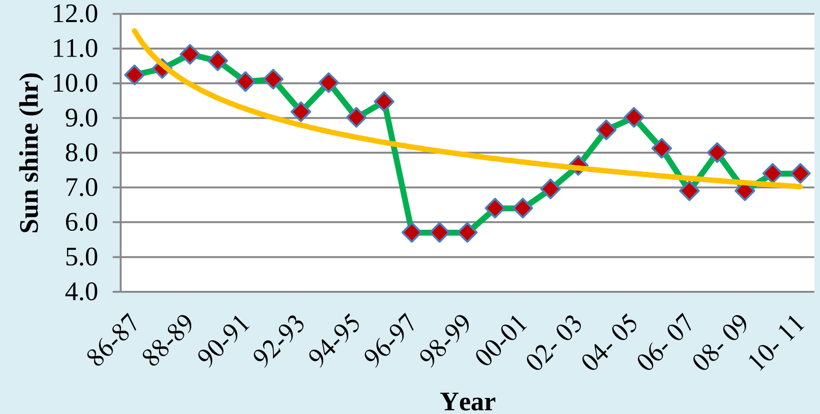


Fig.62 -Logarithmic trend of sun shine hour for the month of Feb.

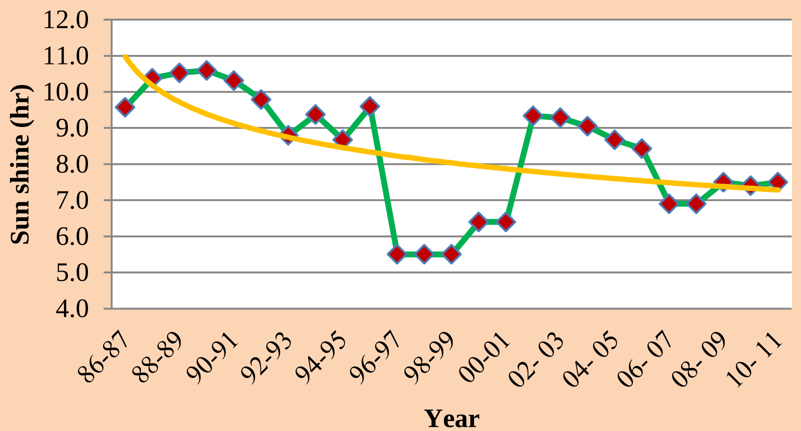


Fig.63 -Logarithmic trend of sun shine hour for the month of Mar.

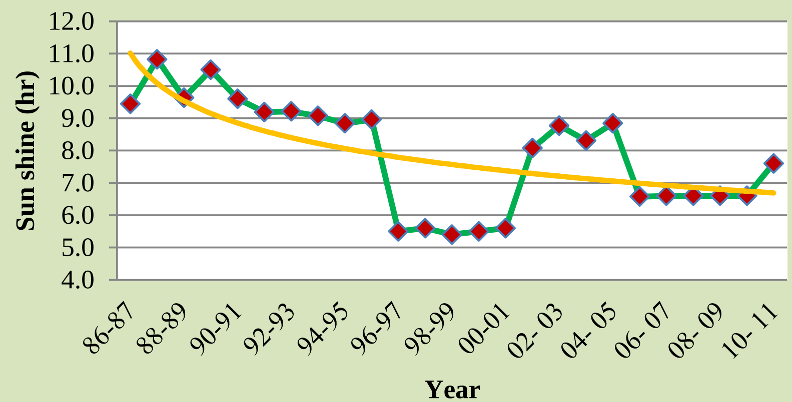


Fig.64 -Logarithmic trend of sun shine hour for the month of Apr.

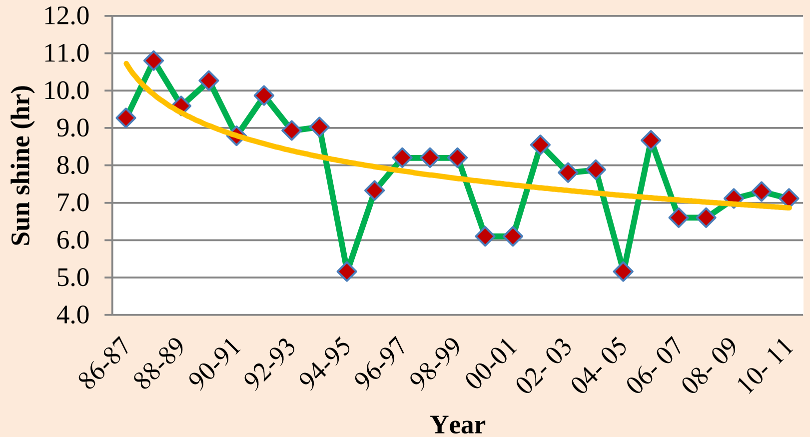


Fig. 65 -Logarithmic trend of sun shine hour for the month of May

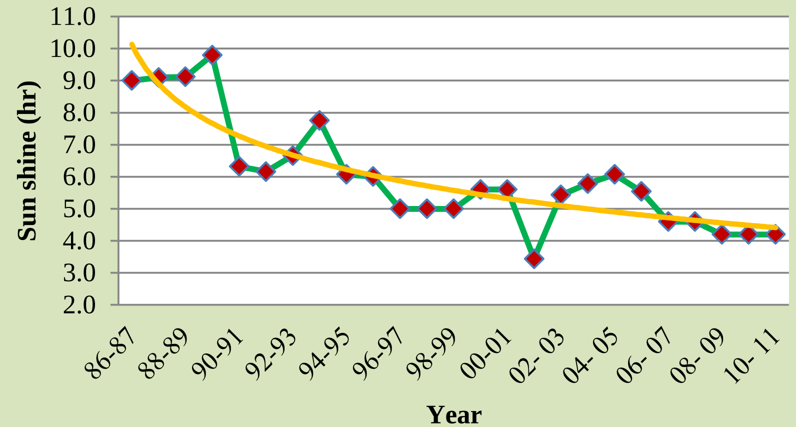


Fig. 66 -Logarithmic trend of sun shine hour for the month of Jun.

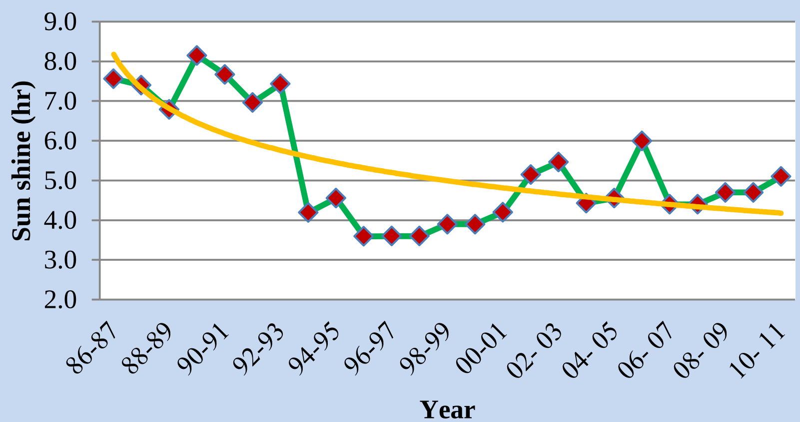


Fig. 67 -Logarithmic trend of sun shine hour for the month of Jul.

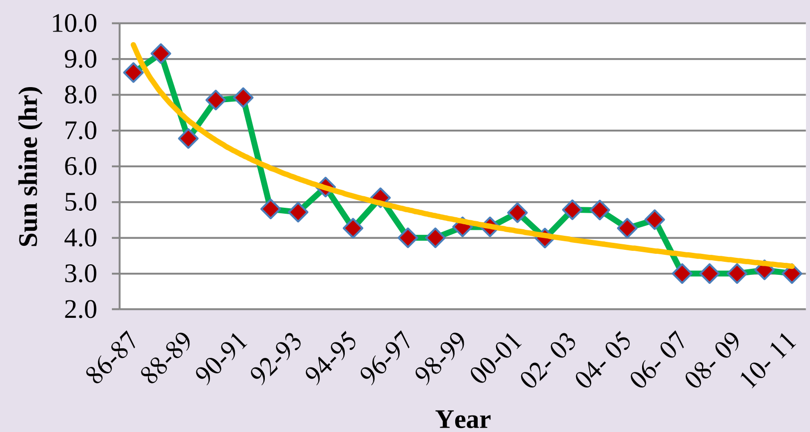


Fig. 68 -Logarithmic trend of sun shine hour for the month of Aug.

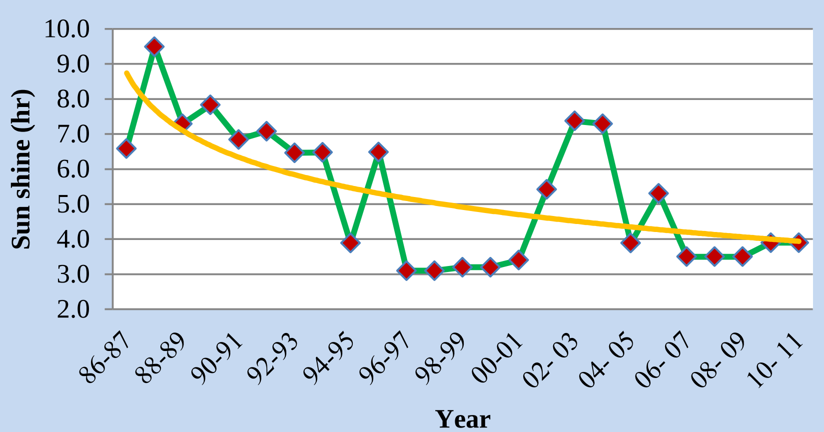


Fig.69 -Logarithmic trend of sun shine hour for the month of Sep.

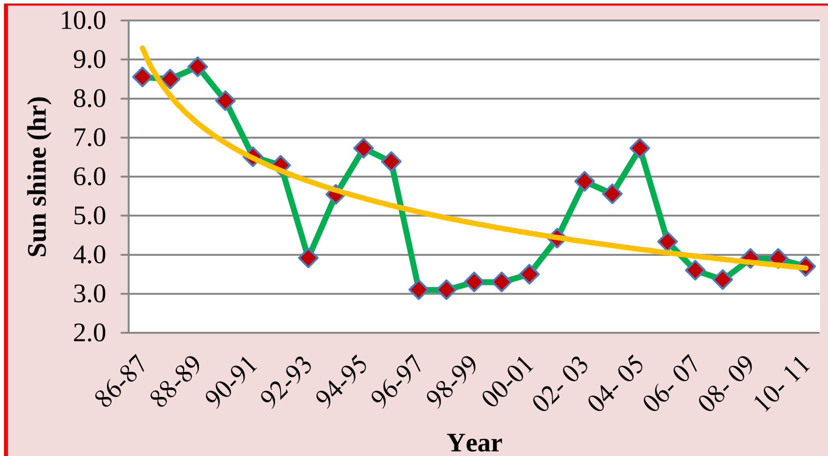


Fig.70-Logarithmic trend of sun shine hour for the month of Oct.

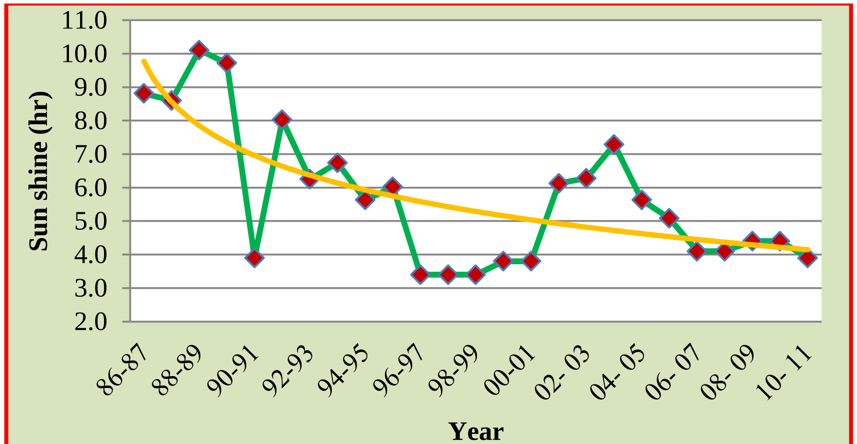


Fig.71-Logarithmic trend of sun shine hour for the month of Nov.

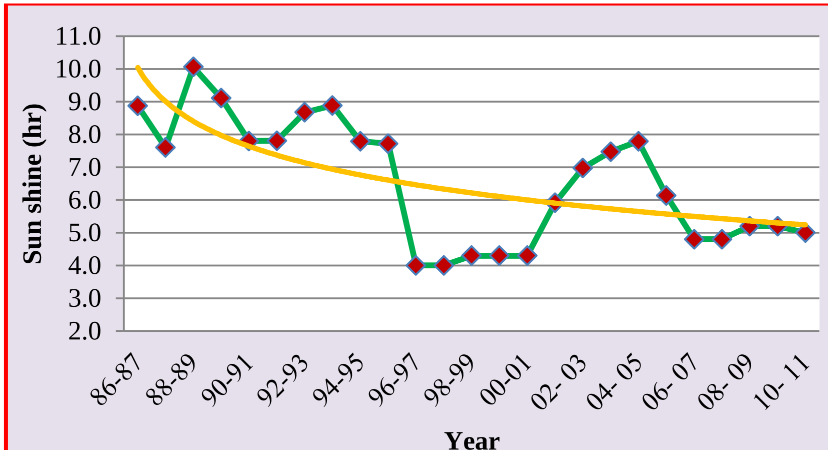


Fig.72-Logrithmic trend of sun shine hour for the month of Dec.

## Rainfall

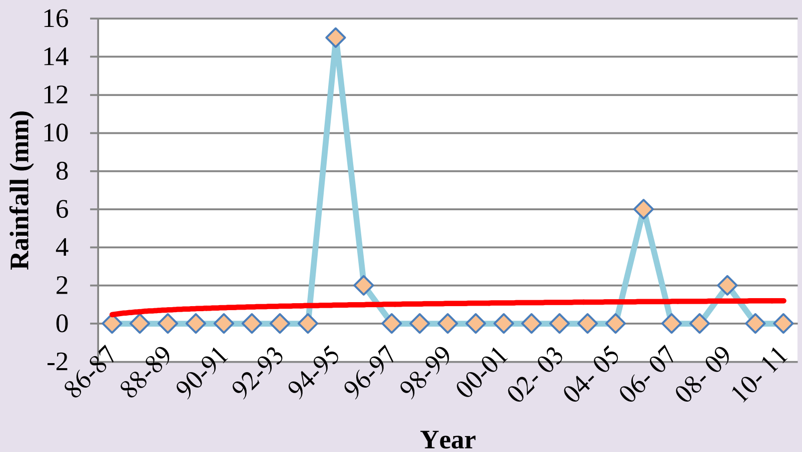


Fig.73 -Logarithmic trend of rainfall for the month of Jan.

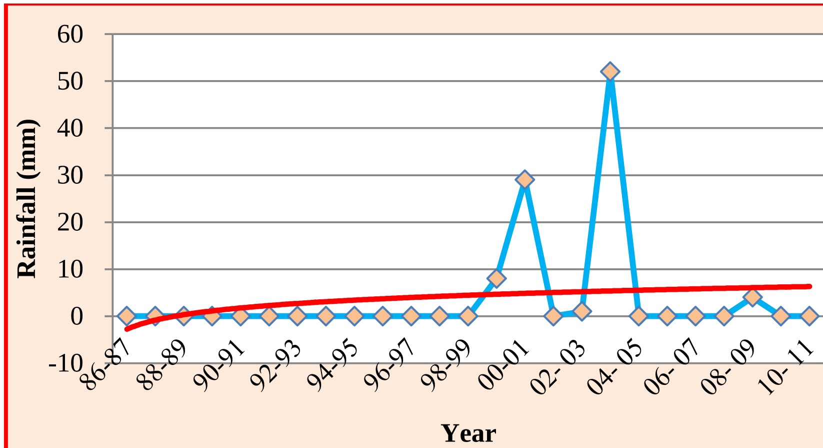


Fig.74 -Logarithmic trend of rainfall for the month of Feb.

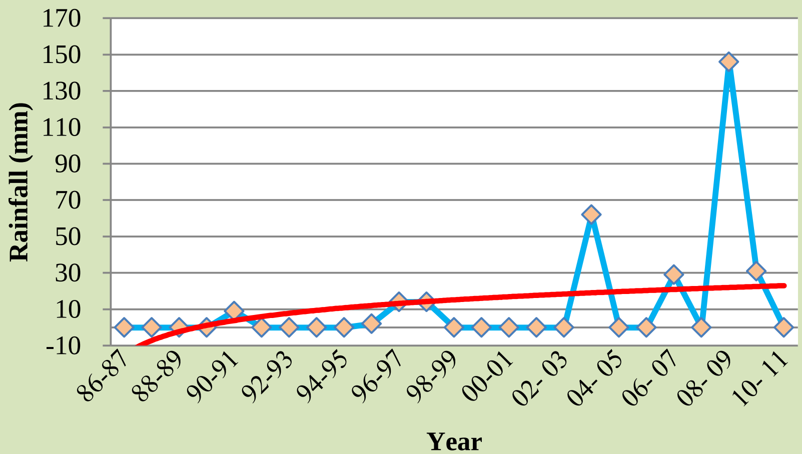


Fig.75 -Logarithmic trend of rainfall for the month of Mar

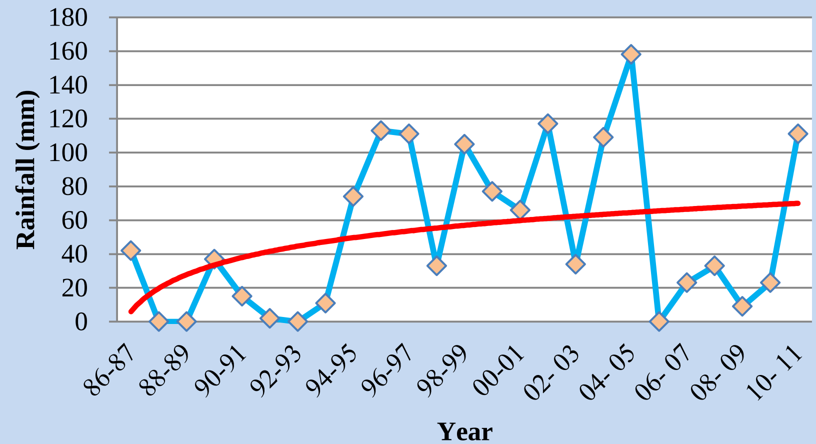


Fig.76 -Logarithmic trend of rainfall for the month of Apr.

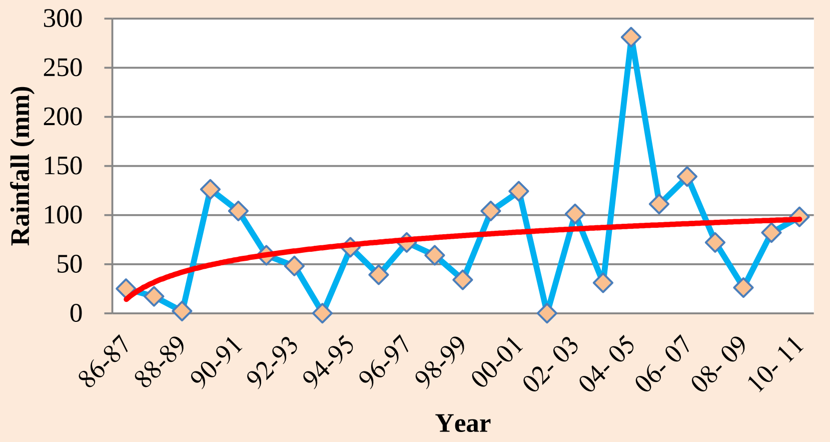


Fig. 77 -Logarithmic trend of rainfall for the month of May

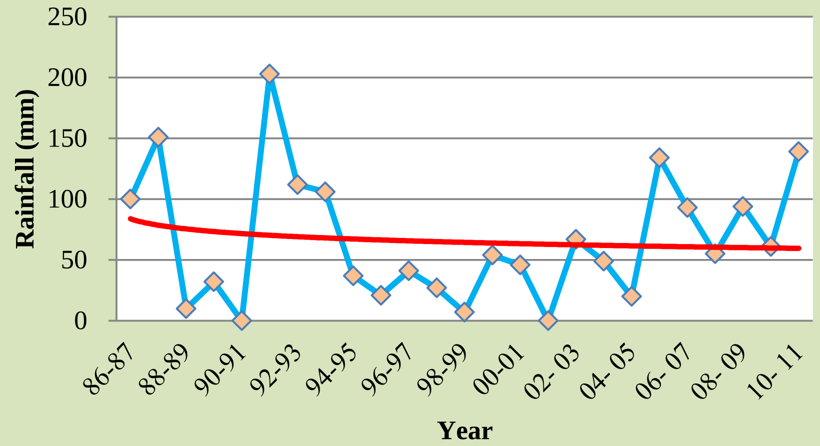


Fig. 78 -Logarithmic trend of rainfall for the month of Jun.

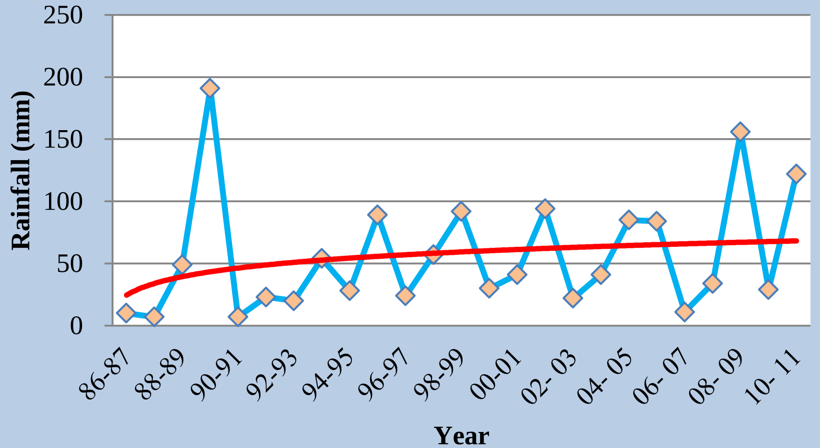


Fig. 79 -Logarithmic trend of rainfall for the month of Jul.

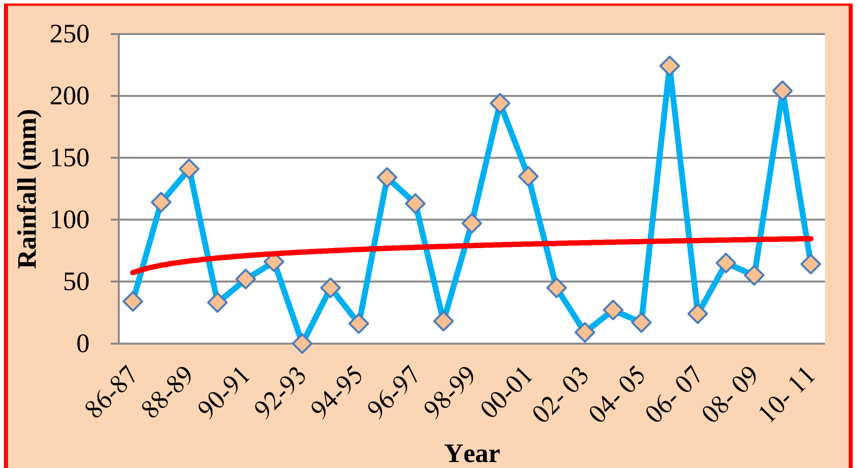


Fig. 80 -Logarithmic trend of rainfall for the month of Aug.

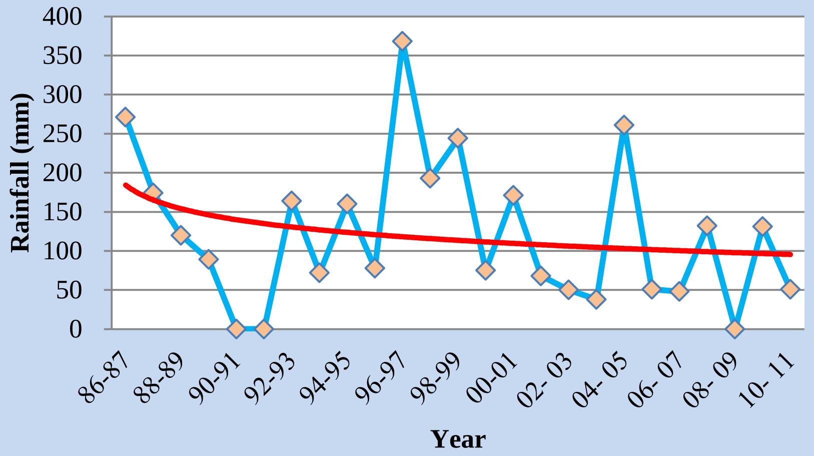


Fig. 81 -Logarithmic trend of rainfall for the month of Sep.

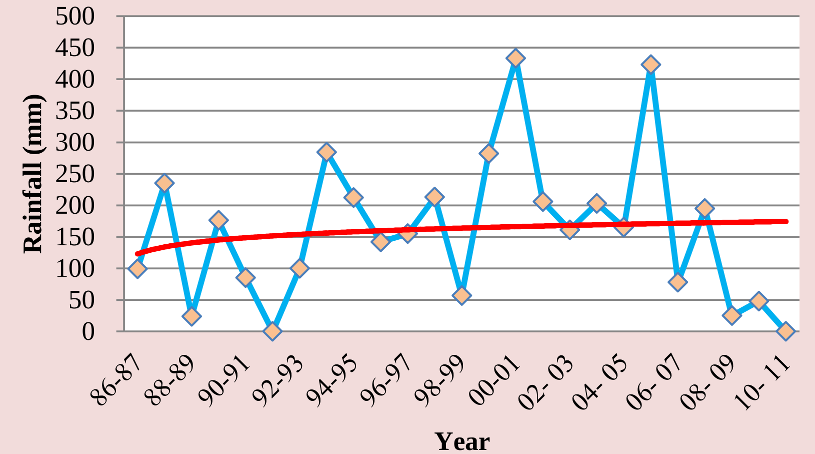


Fig. 82 -Logarithmic trend of rainfall for the month of Oct.

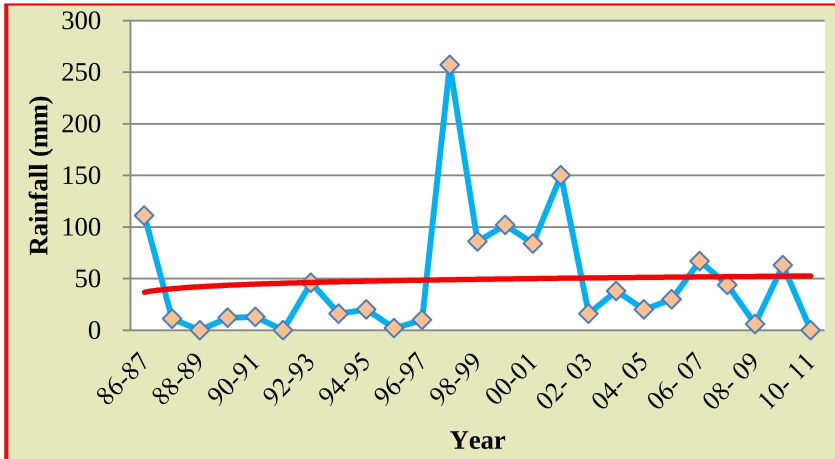


Fig. 83 -Logarithmic trend of rainfall for the month of Nov.

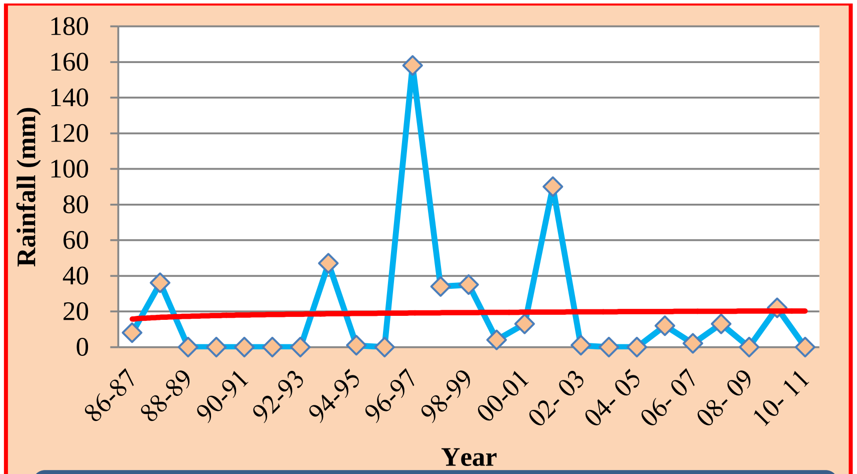


Fig. 84 -Logarithmic trend of rainfall for the month of Dec.

It was found that the rainfall shown a non significant trend during study period for all the months in Linear and Logarithmic model except March in Linear model (Table 4.1.3.7), however it was found to be significant. All the months shows positive trend except January and September in Linear model and June and September in Logarithmic model, these months shows negative trend. The logarithmic model was found to be best model to fit trend for Rainfall as compared to Linear and exponential and model based on $R^2$ values (Fig.73 to Fig.84).

**Table 4.1.3.6: Fitted regression equations for sun shine hour during the period 1986 to 2010**

| Month | Linear (b) | $R^2$ Value | Exponential (b) | $R^2$ Value | Logarithmic (b) | $R^2$ Value |
|---|---|---|---|---|---|---|
| JAN | $-0.137^{**}$ | 0.413 | $-0.017^{**}$ | 0.348 | $-1.303^{**}$ | 0.478 |
| FEB | $-0.145^{**}$ | 0.400 | $-0.016^{**}$ | 0.331 | $-1.394^{**}$ | 0.476 |
| MAR | $-0.120^{**}$ | 0.287 | $-0.014^{*}$ | 0.226 | $-1.146^{**}$ | 0.337 |
| APR | $-0.142^{**}$ | 0.382 | $-0.017^{**}$ | 0.319 | $-1.344^{**}$ | 0.436 |
| MAY | $-0.129^{**}$ | 0.406 | $-0.016^{**}$ | 0.342 | $-1.199^{**}$ | 0.447 |
| JUN | $-0.190^{**}$ | 0.668 | $-0.030^{**}$ | 0.673 | $-1.777^{**}$ | 0.748 |
| JUL | $-0.118^{**}$ | 0.342 | $-0.019^{**}$ | 0.278 | $-1.242^{**}$ | 0.490 |
| AUG | $-0.202^{**}$ | 0.702 | $-0.039^{**}$ | 0.760 | $-1.924^{**}$ | 0.820 |
| SEP | $-0.161^{**}$ | 0.388 | $-0.029^{**}$ | 0.353 | $-1.491^{**}$ | 0.425 |
| OCT | $-0.175^{**}$ | 0.464 | $-0.031^{**}$ | 0.408 | $-1.749^{**}$ | 0.595 |
| NOV | $-0.176^{**}$ | 0.394 | $-0.027^{**}$ | 0.333 | $-1.748^{**}$ | 0.500 |
| DEC | $-0.166^{**}$ | 0.423 | $-0.02^{**}$ | 0.360 | $-1.490^{**}$ | 0.438 |

****** Significant at 1% level, ***** Significant at 5% level,

**Table 4.1.3.7: Fitted regression equations for rainfall during the period 1986 to 2010**

| Month | Linear (b) | $R^2$ Value | Logarithmic(b) | $R^2$ Value |
|---|---|---|---|---|
| JAN | $-0.003^{NS}$ | 0.001 | $0.227^{NS}$ | 0.003 |
| FEB | $0.284^{NS}$ | 0.032 | $2.827^{NS}$ | 0.040 |
| MAR | $1.710^{*}$ | 0.160 | $11.910^{NS}$ | 0.100 |
| APR | $1.868^{NS}$ | 0.082 | $19.910^{NS}$ | 0.120 |
| MAY | $2.853^{NS}$ | 0.122 | $25.310^{NS}$ | 0.123 |
| JUN | $0.033^{NS}$ | 0.003 | $-7.540^{NS}$ | 0.014 |
| JUL | $1.557^{NS}$ | 0.057 | $13.570^{NS}$ | 0.056 |
| AUG | $1.228^{NS}$ | 0.019 | $8.532^{NS}$ | 0.012 |
| SEP | $-2.888^{NS}$ | 0.050 | $-27.50^{NS}$ | 0.059 |
| OCT | $0.337^{NS}$ | 0.000 | $16.000^{NS}$ | 0.013 |
| NOV | $0.465^{NS}$ | 0.003 | $4.893^{NS}$ | 0.004 |
| DEC | $-0.244^{NS}$ | 0.002 | $1.430^{NS}$ | 0.001 |

***** Significant at 5% level, NS: Non Significant

## 4.2 Influence of weather parameters on the productivity of ragi and sugarcane by Path coefficient analysis

The productivity of ragi and sugarcane were considered as dependent variables and weather parameters viz., maximum temperature, minimum temperature, relative humidity, cloudiness, wind speed, sun shine hour and rainfall were considered as independent variables. Further statistical analysis carried out using path coefficient analysis to know the direct and indirect effect of above selected weather parameters on the productivity of ragi and sugarcane. The results of path analysis for the data during 1991-2010 are presented below.

### 4.2.1 Correlation matrix between weather parameters and the productivity of ragi during 1991-2010

The correlation coefficients for the different pairs of variables are assessed and shown in Table 4.2.1. The productivity of ragi is positively correlated with minimum temperature (0.052), wind speed (0.020) and rainfall (0.555). However, negatively correlated with maximum temperature (0.110), relative humidity (0.031), cloudiness (0.280) and sun shine hour (0.452). From the Table it was noticed that the sun shine hour and rainfall have significant relationship with the ragi productivity. These components exhibited interrelationship with each other. This shows that the importance of these components as yield attributing factors.

**Table 4.2.1: Inter relationship between productivity of ragi and weather parameters**

| Parameters | Ragi | Max. Temp. | Min. Temp. | Relative humidity | Cloudiness | Wind speed | Sun shine hour | Rainfall |
|---|---|---|---|---|---|---|---|---|
| Ragi | 1 | | | | | | | |
| Max. temp. | -0.110 | 1 | | | | | | |
| Min. temp. | 0.052 | -0.055 | 1 | | | | | |
| Relative humidity | -0.031 | 0.456* | 0.114 | 1 | | | | |
| Cloudiness | -0.280 | -0.286 | -0.306 | 0.012 | 1 | | | |
| Wind speed | 0.020 | -0.084 | -0.154 | -0.449* | -0.125 | 1 | | |
| Sun shine hour | -0.452* | -0.041 | -0.364 | -0.364 | 0.566** | 0.552* | 1 | |
| Rainfall | 0.555* | -0.254 | 0.029 | -0.254 | -0.307 | -0.059 | -0.497* | 1 |

****** Significant at 1% level, ***** Significant at 5% level, Other values are non significant

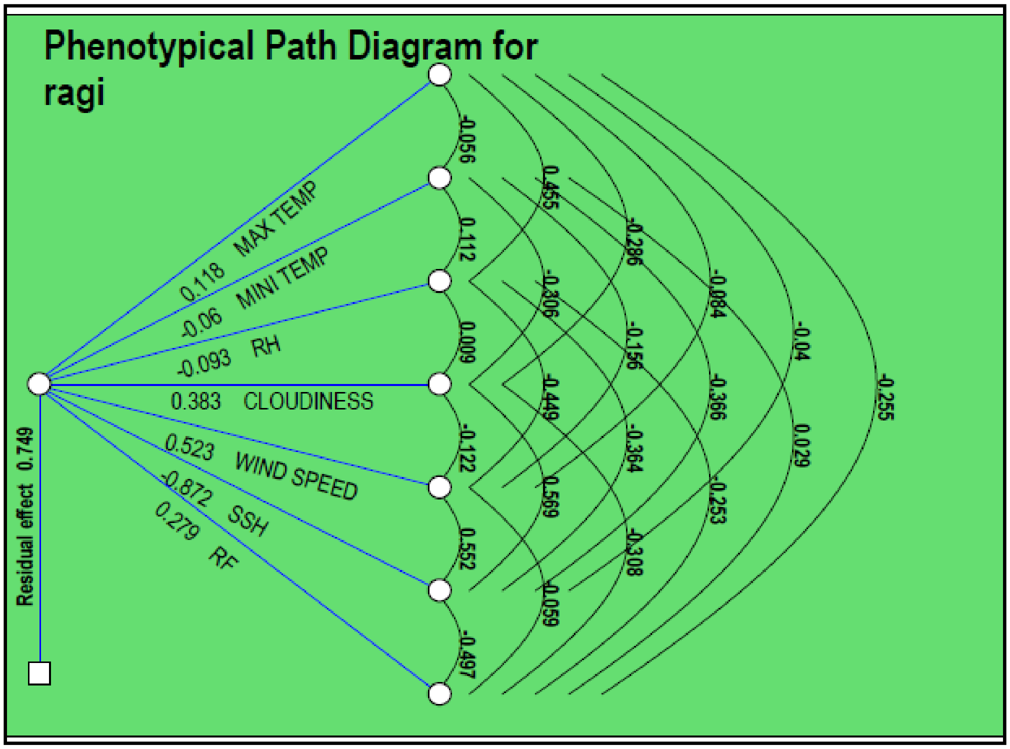


**Fig. 85- Path diagram showing the productivity of ragi crop**

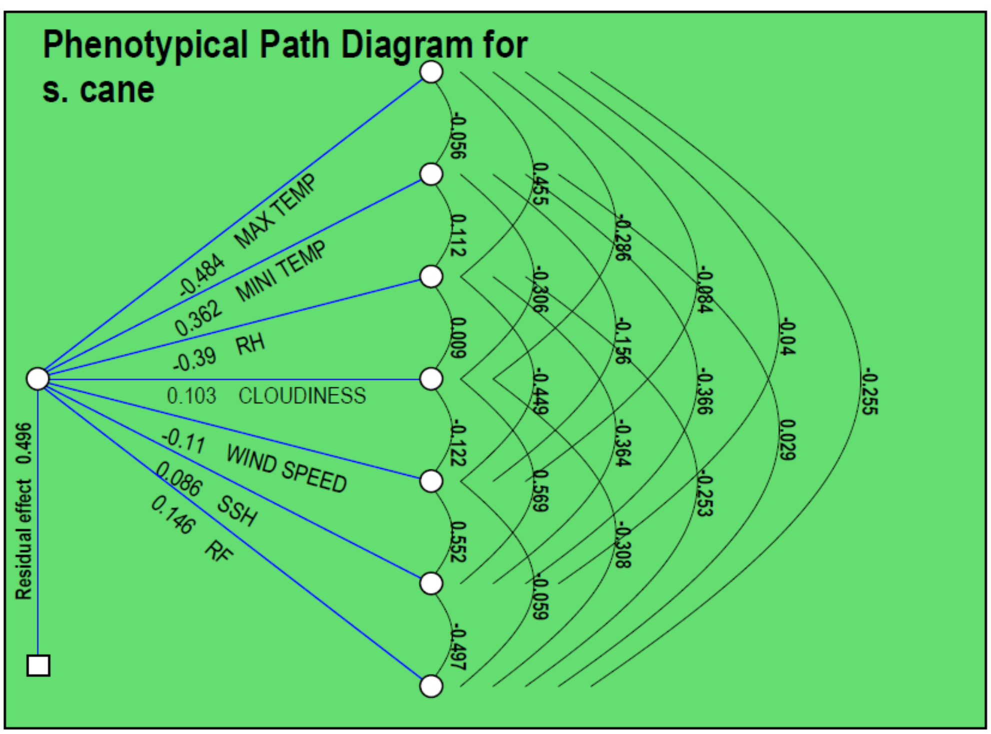


**Fig. 86- Path diagram showing the productivity of sugarcane crop**

### 4.2.2 Correlation matrix between weather parameters and the productivity of sugarcane during 1991-2010

The correlation coefficients for the different pairs of variables are assessed and shown in Table 4.2.2. The productivity of sugarcane is positively correlated with minimum temperature (0.304), cloudiness (0.144), wind speed (0.076), sun shine hour (0.040) and rainfall (0.311). However, significant negatively correlated with maximum temperature (0.743) and relative humidity (0.587). All these components exhibited interrelationship with each other. This shows that the importance of these components as yield attributing factors.

**Table 4.2.2: Inter relationship between productivity of sugarcane and weather parameters**

| Parameters | Sugar cane | Max. Temp. | Min. Temp. | Relative humidity | Cloudiness | Wind speed | Sun shine hour | Rainfall |
|---|---|---|---|---|---|---|---|---|
| Sugarcane | 1 | | | | | | | |
| Max. Temp. | -0.743** | 1 | | | | | | |
| Min. Temp. | 0.304 | -0.056 | 1 | | | | | |
| Relative humidity | -0.587** | 0.455* | 0.112 | 1 | | | | |
| Cloudiness | 0.144 | -0.286 | -0.306 | 0.009 | 1 | | | |
| Wind speed | 0.076 | -0.084 | -0.156 | -0.449* | -0.122 | 1 | | |
| Sun shine hour | 0.040 | -0.040 | -0.366 | -0.364 | 0.569** | 0.552* | 1 | |
| Rainfall | 0.311 | -0.255 | 0.029 | -0.253 | -0.308 | -0.059 | -0.497* | 1 |

****** Significant at 1% level, ***** Significant at 5% level, Other values are non significant

### 4.2.3 Path coefficients showing direct and indirect effects of weather parameters on the productivity of ragi during 1991-2010

The analysis shows that diagonal elements represent direct effects and off diagonal elements represent indirect effects (Table 4.2.3). This indicates that the wind speed had high positive direct effect of 0.5228 followed by cloudiness (0.3830) and rainfall (0.2785). The correlation between productivity of ragi and rainfall (0.555) was high and positive followed by minimum temperature and wind speed. Hence the productivity of ragi is more depends on rainfall. The diagram showing direct and indirect effects on productivity of ragi has been presented in figure 85.

The residual value obtained was 0.7488 (shown in figure 85). It indicates that 75% of variation in the productivity of ragi was accounted by other factors; only 25% of variation in the productivity of ragi was accounted by seven selected weather parameters.

**Table 4.2.3: Path coefficient analysis between selected weather parameters with productivity of ragi**

| Parameters | Max. Temp. | Min. Temp. | Relative humidity | Cloudiness | Wind speed | Sun shine hour | Rainfall |
|---|---|---|---|---|---|---|---|
| Max. Temp. | **0.1179** | -0.0066 | 0.0537 | -0.0338 | -0.0099 | -0.0048 | -0.0301 |
| Min. Temp. | 0.0033 | **-0.0595** | -0.0067 | 0.0182 | 0.0093 | 0.0218 | -0.0017 |
| RH | -0.0425 | -0.0105 | **-0.0933** | -0.0009 | 0.0419 | 0.0339 | 0.0236 |
| Cloudiness | -0.1096 | -0.1174 | 0.0036 | **0.3830** | -0.0466 | 0.2179 | -0.1178 |
| WS | -0.0439 | -0.0814 | -0.2348 | -0.0636 | **0.5228** | 0.2887 | -0.0308 |
| SSH | 0.0352 | 0.3190 | 0.3171 | -0.4959 | -0.4814 | **-0.8716** | 0.4335 |
| RF | -0.077 | 0.0081 | -0.0706 | -0.0857 | -0.0164 | -0.1385 | **0.2785** |

### 4.2.4 Path coefficients showing direct and indirect effects of weather parameters on the productivity of sugarcane during 1991-2010

The analysis shows that the minimum temperature had high positive direct effect of 0.3623 followed by rainfall (0.1465) and cloudiness (0.1025) whereas maximum temperature, relative humidity, and wind speed has negative direct effect on the productivity of sugarcane (Table 4.2.4). The correlation between productivity of sugarcane and rainfall (0.311) was found to be high and positive followed by minimum temperature (0.304). Hence, the productivity of sugarcane is more depends on rainfall and minimum temperature. The diagram showing direct and indirect effects on productivity of sugarcane has been presented in figure 86.

The residual value obtained was 0.4961 (shown in figure 86). It indicates that 50% of variation in the productivity of sugarcane was accounted by other factors and remaining 50 percent of variation in the productivity of sugarcane was accounted by seven selected weather parameters.

**Table 4.2.4: Path coefficient analysis between selected weather parameters with productivity of sugarcane**

| Parameters | Max. Temp. | Min. Temp. | Relative humidity | Cloudiness | Wind speed | Sun shine | Rainfall |
|---|---|---|---|---|---|---|---|
| Max. Temp. | **-0.4839** | 0.0271 | -0.2204 | 0.1385 | 0.0407 | 0.0195 | 0.1235 |
| Min. Temp. | -0.0203 | **0.3623** | 0.0407 | -0.1110 | -0.0564 | -0.1326 | 0.0106 |
| RH | -0.1775 | -0.0438 | **-0.3897** | -0.0037 | 0.1750 | 0.1418 | 0.0987 |
| Cloudiness | -0.0294 | -0.0314 | 0.0010 | **0.1025** | -0.0125 | 0.0583 | -0.0315 |
| WS | 0.0093 | 0.0172 | 0.0495 | 0.0134 | **-0.1103** | -0.0609 | 0.0065 |
| SSH | -0.0035 | -0.0316 | -0.0314 | 0.0492 | 0.0477 | **0.0864** | -0.0430 |
| RF | -0.0374 | 0.0043 | -0.0371 | -0.0450 | -0.0086 | -0.0728 | **0.1465** |

### 4.2.5 Direct and indirect contribution of weather parameters on productivity of ragi during 1991-2010

#### 4.2.5.1 Direct and indirect contribution of maximum temperature on productivity of ragi during 1991-2010

The study reveals that the direct contribution of maximum temperature on productivity of ragi was found to be 0.1179 and indirect contribution was found to be negative (0.0852) and positive (0.0537) (Table 4.2.5.1). The total contribution of maximum temperature was 0.0864. The contribution of this maximum temperature was found to be higher after cloudiness and wind speed and it has direct positive influence on the productivity of ragi.

**Table 4.2.5.1: Maximum temperature and productivity of ragi**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Max. temp. | 0.1179 | |
| Indirect contribution (IC) | Min. temp. | | 0.0066 |
| | Relative humidity | 0.0537 | |
| | Cloudiness | | 0.0338 |
| | Wind speed | | 0.0099 |
| | Sun shine hour | | 0.0048 |
| | Rainfall | | 0.0301 |
| **Total (IC)** | | 0.0537 | 0.0852 |
| **Total (DC+IC)** | | 0.0867 | |

#### 4.2.5.2 Direct and indirect contribution of minimum temperature on productivity of ragi during 1991-2010

The result shows that the minimum temperature had a negative direct effect of -0.0595 and indirect contribution was found to be negative (0.0084) and positive (0.0526) (Table 4.2.5.2). The total contribution of minimum temperature on the productivity of ragi was found to be negative and it was -0.0153. Therefore the productivity of ragi was indirectly influenced by the minimum temperature.

**Table 4.2.5.2: Minimum temperature and productivity of ragi**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Min. temp. | | 0.0595 |
| Indirect contribution (IC) | Max. temp. | 0.0033 | |
| | Relative humidity | | 0.0067 |
| | Cloudiness | 0.0182 | |
| | Wind speed | 0.0093 | |
| | Sun shine hour | 0.0218 | |
| | Rainfall | | 0.0017 |
| **Total (IC)** | | 0.0526 | 0.0084 |
| **Total (DC+IC)** | | | 0.0153 |

### 4.2.5.3 Direct and indirect contribution of relative humidity on productivity of ragi during 1991-2010

The results indicated that, the relative humidity had a negative direct effect of -0.0933 and indirect contribution was found to be negative (0.0539) and positive (0.0994) (Table 4.2.5.3). The total contribution of relative humidity on the productivity of ragi was found to be negative and it was -0.0478. Therefore the productivity of ragi was indirectly influenced by the relative humidity.

**Table 4.2.5.3: Relative humidity and productivity of ragi**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Relative humidity | | 0.0933 |
| Indirect contribution (IC) | Max. temp. | | 0.0425 |
| | Min. temp. | | 0.0105 |
| | Cloudiness | | 0.0009 |
| | Wind speed | 0.0419 | |
| | Sun shine hour | 0.0339 | |
| | Rainfall | 0.0236 | |
| **Total (IC)** | | 0.0994 | 0.0539 |
| **Total (DC+IC)** | | | 0.0478 |

### 4.2.5.4 Direct and indirect contribution of cloudiness on productivity of ragi during 1991-2010

It was depicted that the direct contribution of cloudiness on productivity of ragi was found to be 0.3830 and indirect contribution was found to be negative (0.3914) and positive (0.2215). The total contribution of cloudiness was 0.2131. The contribution of this cloudiness was found to be higher after wind speed and it has direct positive influence on the productivity of ragi (Table 4.2.5.4)

**Table 4.2.5.4: Cloudiness and productivity of ragi**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Cloudiness | 0.3830 | |
| Indirect contribution (IC) | Max. temp. | | 0.1096 |
| | Min. temp. | | 0.1174 |
| | Relative humidity | 0.0036 | |
| | Wind speed | | 0.0466 |
| | Sun shine hour | 0.2179 | |
| | Rainfall | | 0.1178 |
| **Total (IC)** | | 0.2215 | 0.3914 |
| **Total (DC+IC)** | | 0.2131 | |

#### 4.2.5.5 Direct and indirect contribution of wind speed on productivity of ragi during 1991-2010

The direct contribution of wind speed on productivity of ragi was found to be 0.5228 and indirect contribution was found to be negative (0.4545) and positive (0.2887). The total contribution of wind speed was 0.3570. The contribution of this wind speed was found to be higher compared to other weather parameters and it has direct positive influence on the productivity of ragi (Table 4.2.5.5).

**Table 4.2.5.5: Wind speed and productivity of ragi**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Wind speed | 0.5228 | |
| Indirect contribution (IC) | Max. temp. | | 0.0439 |
| | Min. temp. | | 0.0814 |
| | Relative humidity | | 0.2348 |
| | Cloudiness | | 0.0636 |
| | Sun shine hour | 0.2887 | |
| | Rainfall | | 0.0308 |
| **Total (IC)** | | 0.2887 | 0.4545 |
| **Total (DC+IC)** | | 0.3570 | |

#### 4.2.5.6 Direct and indirect contribution of sun shine hour on productivity of ragi during 1991-2010

The result shows that the sun shine hour had a negative direct effect of 0.8716 and indirect contribution was found to be positive (1.1048) and negative (0.9773). The total contribution of sun shine on the productivity of ragi was found to be negative and it was 0.7441. Therefore the productivity of ragi was indirectly influenced by the sun shine hour (Table 4.2.5.6).

**Table 4.2.5.6: Sun shine hour and productivity of ragi**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Sun shine hour | | 0.8716 |
| Indirect contribution (IC) | Max. temp. | 0.0352 | |
| | Min. temp. | 0.3190 | |
| | Relative humidity | 0.3171 | |
| | Cloudiness | | 0.4959 |
| | Wind speed | | 0.4814 |
| | Rainfall | 0.4335 | |
| **Total (IC)** | | 1.1048 | 0.9773 |
| **Total (DC+IC)** | | | 0.7441 |

### 4.2.5.7 Direct and indirect contribution of rainfall on productivity of ragi during 1991-2010

The direct contribution of rainfall on productivity of ragi was found to be 0.2785 and indirect contribution was found to be negative (0.3823) and positive (0.0081). The total contribution of rainfall was negative and it was found to be -0.0957. The contribution of this rainfall was found to be higher after wind speed and cloudiness and it has direct positive influence on the productivity of ragi (Table 4.2.5.7).

**Table 4.2.5.7: Rainfall and productivity of ragi**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Rainfall | 0.2785 | |
| Indirect contribution (IC) | Max. temp. | | 0.0711 |
| | Min. temp. | 0.0081 | |
| | Relative humidity | | 0.0706 |
| | Cloudiness | | 0.0857 |
| | Wind speed | | 0.0164 |
| | Sun shine hour | | 0.1385 |
| **Total (IC)** | | 0.0081 | 0.3823 |
| **Total (DC+IC)** | | | 0.0957 |

### 4.2.5.8 Percentage contribution of weather parameters on the productivity of ragi during 1991-2010

The results indicates per cent contribution of each of selected weather parameters on the productivity of ragi (Table 4.2.5.8). It was observed that, sun shine hour contribution was higher and was found to be 75.97 per cent, followed by wind speed (27.33%), cloudiness (14.67%), and rainfall (7.76%). The lowest contribution towards the productivity of ragi was minimum temperature (0.35%), relative humidity (0.87%) and maximum temperature (1.39%).

**Table 4.2.5.8: Percentage contribution of selected weather parameters on productivity of ragi during study period**

| No. | Parameters | Contribution (%) |
|---|---|---|
| 1 | Maximum temperature | 1.39 |
| 2 | Minimum temperature | 0.35 |
| 3 | Relative humidity | 0.87 |
| 4 | Cloudiness | 14.67 |
| 5 | Wind speed | 27.33 |
| 6 | Sun shine hour | 75.97 |
| 7 | Rainfall | 7.76 |

### 4.2.6 Direct and indirect contribution of weather parameters on productivity of sugarcane during 1991-2010

#### 4.2.6.1 Direct and indirect contribution of maximum temperature on productivity of sugarcane during 1991-2010

The result shows that, direct positive contribution of maximum temperature on productivity of sugarcane was found to be 0.4839 and indirect contribution was found to be positive (0.3493) and negative (0.2204). The total contribution of maximum temperature was 0.6128 (Table 4.2.6.1). The contribution of this maximum temperature was found to be higher when compared to other weather parameters and it has direct positive influence on the productivity of sugarcane.

**Table 4.2.6.1: Maximum temperature and productivity of sugarcane**

| Effect | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Max. temp. | 0.4839 | |
| Indirect contribution (IC) | Min. temp. | 0.0271 | |
| | Relative humidity | | 0.2204 |
| | Cloudiness | 0.1385 | |
| | Wind speed | 0.0407 | |
| | Sun shine hour | 0.0195 | |
| | Rainfall hour | 0.1235 | |
| **Total (IC)** | | 0.3493 | 0.2204 |
| **Total (DC+IC)** | | 0.6128 | |

#### 4.2.6.2 Direct and indirect contribution of minimum temperature on productivity of sugarcane during 1991-2010

The minimum temperature had a positive direct effect of 0.3623 and indirect contribution was found to be negative (0.3203) and positive (0.0513) (Table 4.2.6.2). The total contribution of minimum temperature on the productivity of sugarcane was found to be 0.0933. Therefore the productivity of sugarcane was directly influenced by the minimum temperature.

**Table 4.2.6.2: Minimum temperature and productivity of sugarcane**

| Effect | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Min. temp. | 0.3623 | |
| Indirect contribution (IC) | Max. temp. | | 0.0203 |
| | Relative humidity | 0.0407 | |
| | Cloudiness | | 0.1110 |
| | Wind speed | | 0.0564 |
| | Sun shine hour | | 0.1326 |
| | Rainfall | 0.0106 | |
| **Total (IC)** | | 0.0513 | 0.3203 |
| **Total (DC+IC)** | | 0.0933 | |

#### 4.2.6.3 Direct and indirect contribution of relative humidity on productivity of sugarcane during 1991-2010

The result shows that the relative humidity had a negative direct effect of -0.3897 and indirect contribution was found to be positive (0.4155) and negative (0.2250) (Table 4.2.6.3). The total contribution of relative humidity on the productivity of sugarcane was found to be negative and it was -0.1992. Therefore, the productivity of sugarcane was indirectly influenced by the relative humidity.

**Table 4.2.6.3: Relative humidity and productivity of sugarcane**

| Effect | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Relative humidity | | 0.3897 |
| Indirect contribution (IC) | Max. temp. | | 0.1775 |
| | Min. temp. | | 0.0438 |
| | Cloudiness | | 0.0037 |
| | Wind speed | 0.1750 | |
| | Sun shine hour | 0.1418 | |
| | Rainfall | 0.0987 | |
| **Total (IC)** | | 0.4155 | 0.2250 |
| **Total (DC+IC)** | | | 0.1992 |

#### 4.2.6.4 Direct and indirect contribution of cloudiness on productivity of sugarcane during 1991-2010

It was depicted that the direct contribution of cloudiness on productivity of sugarcane was found to be 0.1025 and indirect contribution was found to be negative (0.1048) and positive (0.0593). The total contribution of cloudiness was 0.0570. The cloudiness has direct positive influence on the productivity of sugarcane (Table 4.2.6.4).

**Table 4.2.6.4: Cloudiness and productivity of sugarcane**

| Effect | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Cloudiness | 0.1025 | |
| Indirect contribution (IC) | Max. temp. | | 0.0294 |
| | Min. temp. | | 0.0314 |
| | Relative humidity | 0.0010 | |
| | Wind speed | | 0.0125 |
| | Sun shine hour | | 0.0583 |
| | Rainfall | 0.0315 | |
| **Total (IC)** | | 0.0593 | 0.1048 |
| **Total (DC+IC)** | | 0.0570 | |

#### 4.2.6.5 Direct and indirect contribution of wind speed on productivity of sugarcane during 1991-2010

The direct contribution of wind speed on productivity of sugarcane was found to be -0.1103 and indirect contribution was found to be positive (0.0959) and negative (0.0609). The total contribution of wind speed was -0.0753. Wind speed has direct negative effect on the productivity of sugarcane (Table 4.2.6.5)

**Table 4.2.6.5: Wind speed and productivity of sugarcane**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Wind speed | | 0.1103 |
| Indirect contribution (IC) | Max. temp. | 0.0093 | |
| | Min. temp. | 0.0172 | |
| | Relative humidity | 0.0495 | |
| | Cloudiness | 0.0134 | |
| | Sun shine hour | | 0.0609 |
| | Rainfall | 0.0065 | |
| **Total (IC)** | | 0.0959 | 0.0609 |
| **Total (DC+IC)** | | | 0.0753 |

#### 4.2.6.6 Direct and indirect contribution of sun shine hour on productivity of sugarcane during 1991-2010

The results presented shows that the sun shine hour had a positive direct effect of 0.0864 and indirect contribution was found to be negative (0.1095) and positive (0.0969). The total contribution of sun shine on the productivity of sugarcane was found to be positive and it was 0.0738. Therefore the productivity of sugarcane was directly influenced by the sun shine hour (Table 4.2.6.6).

**Table 4.2.6.6: Sun shine hour and productivity of sugarcane**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Sun shine hour | 0.0864 | |
| Indirect contribution (IC) | Max. temp. | | 0.0035 |
| | Min. temp. | | 0.0316 |
| | Relative humidity | | 0.0314 |
| | Cloudiness | 0.0492 | |
| | Wind speed | 0.0477 | |
| | Rainfall | | 0.0430 |
| **Total (IC)** | | 0.0969 | 0.1095 |
| **Total (DC+IC)** | | 0.0738 | |

### 4.2.6.7 Direct and indirect contribution of rainfall on productivity of sugarcane during 1991-2010

The direct contribution of rainfall on productivity of sugarcane was found to be 0.1465 and indirect contribution was found to be negative (0.2009) and positive (0.0043). The total contribution of rainfall was negative and it was found to be -0.0501. The contribution of this rainfall was found to be higher after maximum and minimum temperature and it has direct positive influence on the productivity of sugarcane (Table 4.2.6.7).

**Table 4.2.6.7: Rainfall and productivity of sugarcane**

| Effects | Parameter | Contributions | |
|---|---|---|---|
| | | Positive | Negative |
| Direct contribution (DC) | Rainfall | 0.1465 | |
| Indirect contribution (IC) | Max. temp. | | 0.0374 |
| | Min. temp. | 0.0043 | |
| | Relative humidity | | 0.0371 |
| | Cloudiness | | 0.0450 |
| | Wind speed | | 0.0086 |
| | Sun shine hour | | 0.0728 |
| **Total (IC)** | | 0.0043 | 0.2009 |
| **Total (DC+IC)** | | | 0.0501 |

### 4.2.6.8 Percentage contribution of weather parameters on the productivity of sugarcane during 1991-2010

The results presented indicates per cent contribution of each of selected weather parameters on the productivity of sugarcane (Table 4.2.6.8). It was observed that, maximum temperature contribution was higher and was approximately found to be 23.42 per cent, followed by relative humidity (15.15%), minimum temperature (13.33%). The lowest contribution towards the productivity of sugarcane was sun shine hour and was found to be 0.75 per cent followed by cloudiness (1.05%), wind speed (1.22%) and rainfall (14.65%).

**Table 4.2.6.8: Percentage contribution of selected weather parameters on productivity of sugarcane during study period**

| No. | Individual contribution | Contribution (%) |
|---|---|---|
| 1 | Maximum temperature | 23.42 |
| 2 | Minimum temperature | 13.13 |
| 3 | Relative humidity | 15.15 |
| 4 | Cloudiness | 1.05 |
| 5 | Wind speed | 1.22 |
| 6 | Sun shine hour | 0.75 |
| 7 | Rainfall | 2.15 |

# V. DISCUSSION

To determine the risk involved in climate changes in the field of agriculture it is necessary to define a set of agro meteorological parameters derived from the climate parameters, which are capable of indicating the consequences of climate change for crop production. Climate is one of the most important limiting factors for agricultural production. Frost risk during the growing period and low and irregular precipitation with high risks of drought during the cultivation period are common problems in agriculture.

Crop yield is considerably more affected by technological and weather variability. Technological changes includes the impact of increased fertilizer applications, better improved management practices and pest control, advanced genetic qualities of seed and other human controlled factors designed to increase yield. Seasonal and intra seasonal variation in weather parameter is uncontrolled independent variables affecting the dependent variable (yield).

Based on the methodologies outlined in chapter III, results obtained were presented in chapter IV and same were discussed in this chapter for each of the objective of the study. 'Impact of weather parameters on Productivity of Selected Crops in Mandya District- A Statistical Approach' under the following objectives.

- To study the trend in the weather parameter over the study period.
- To study the impact of weather parameters on productivity of ragi and sugarcane.

## 5.1 To study the trend in the weather parameter over the study period

Descriptive statistics is an important statistical tools used to know the variability of weather parameters for Mandya district during the study period.

It was observed that fluctuation of the maximum temperature over a study period and it was found to be optimum in the month of April and it has extended to May and June. During summer, the Coefficient of variation is at higher side (Rober Scott, 2002). Small change in temperature mean results in a relatively high increase in the probability of temperature extremes (Folland *et al*., 1999).

The maximum and minimum temperature shows more or less similar variability over a study period. In summer season, the minimum temperature was found to be less as compared to maximum temperature. Similar findings established by Prabhjyot *et al.* (2006) for Ludhiana with higher variability and asymmetrical distribution of temperature over time. An increase, even moderate temperature is expected to result in frequency of extreme weather events like drought, heavy rainfall and storms (Balling and Idos, 1990).

The relative humidity and cloudiness were found to be more or less optimum and uniform during the study period. The relative humidity found high in the month of April and cloudiness is more during the month of October.

The study established more variability in the wind speed during study period and more in the month of July because of monsoon and coefficient of variation was found to be more in the month of November. Human interference is also leading to climate change with changing land use, impact of agricultural and irrigation practices *(Kalnay and Cai, 2003)*.

The sun shine hour was found to be more in summer (January to April) and it has extended to May and more variation was found in the month of October.

It was found that rainfall was more in the month of September and October as compared to the rainy months (May to August) and more variation was found in the month of January. Small change in precipitation mean result in a relatively high increase in the probability of precipitation extremes (Waggoner, 1989; Groisman *et al*., 1999).

**Test for Randomness (Run test) and normality of Error terms**

The error terms were evaluated for their randomness using run test and the results indicate that the error terms are randomly distributed for the fitted models. The normality of error terms were tested using Anderson-Darling test statistic and Shapiro-Wilk test. The test statistics is found to be non significant indicates that the recorded data was said to be normally distributed.

**Trend Analysis**

The maximum temperature showing a significant trend over a period of time for all the months except March and May in Linear and Exponential model and February, March and May in Logarithmic model and these months were found to be non significant. All the months shown positive trend except June, which shows negative trend but it seems to be influenced by changes in the surroundings (micro climate) of the station (Jacob and Anil, 2006). The linear model was found to be best model to fit trend for maximum temperature as compared to exponential and logarithmic model based on $R^2$ values. Most of the trends shown positive change in temperature with different rates that is the maximum temperature at Mumbai during winter and monsoon is significantly increasing (Amit *et. al.*, 2009).

The minimum temperature showing a non significant trend over a period of time for all the months except April and July in Linear and Exponential model, however these months were found to be significant. Most of the months shown negative trend except January. However, March to August months has shown positive trend. The minimum temperature at Mumbai during winter and monsoon is significantly decreasing (Amit *et. al.*, 2009).

Relative humidity has shown a non significant trend during study period in most of the months. All the months has shown positive trend except September in Linear and Exponential model compared to Logarithmic model (June, July, and September). These months shown negative trend. The linear model was found to be best model to fit trend for relative humidity as compared to both exponential and logarithmic model.

It was found that, the cloudiness has shown a negative significant trend during study period for all the months in Linear, Exponential and Logarithmic model. The linear model was found to be best model to fit trend for cloudiness as compared to exponential and logarithmic model comparatively based on $R^2$ values.

It was found that, the wind speed has shown a non significant trend during study period for all the months in Linear, Exponential and Logarithmic model. All the months shows negative trend except February, April, May, June and October, which shows positive trend. The logarithmic model was found to be best model to fit trend for Wind speed as compared to Linear and exponential model based on $R^2$ values. Wind speed was slightly decreased in Phaltan (Jacob and Anil, 2006).

It was found that the sun shine hour shows a negative significant trend during study period for all the months in Linear, Exponential and Logarithmic model. The logarithmic model was found to be best model to fit trend for sun shine hour as compared to Linear and exponential model.

It was found that the rainfall shows a non significant trend during study period for all the months in Linear and Logarithmic model except March in Linear model. However, these months were found to be significant. All the months shows positive trend except January and September in Linear model and June and September in Logarithmic model, while these months shows negative trend. The logarithmic model was found to be best model to fit trend for rainfall as compared to Linear and exponential model. Rainfall during winter and summer seasons showed insignificant increasing trend (Krishnakumar *et al.*, 2009).

## 5.2 Influence of weather parameters on the productivity of ragi and sugarcane by Path coefficient analysis

### 5.2.1 Correlation Analysis

**Ragi**

The productivity of ragi is positively correlated with minimum temperature, wind speed and rainfall; however negatively correlated with maximum temperature, relative humidity, cloudiness and sun shine hour. It was noticed that the sun shine hour and rainfall have significant relationship with the ragi productivity because ragi is mainly dependent on rainfall and minimum temperature is also important to reduce the incidence of pest and diseases. Thus these components exhibited interrelationship with each other. The productivity of rice, maize, sorghum, and ragi crops negatively influenced with increase in actual average maximum temperature. Productivity of barley, rice, maize, and ragi crops decline due to excessive rain (Ajay Kumar *et al.*, 2014). This shows that the importance of these components as influencing /affecting yield components.

**Sugarcane**

The productivity of sugarcane is positively correlated with minimum temperature, cloudiness, wind speed, sun shine hour and rainfall; however negatively and significantly correlated with maximum temperature and relative humidity. The reason behind that is if there is a high maximum temperature and relative humidity, there will be a more incidence of pest and diseases and ultimately lead to decline in yield. Thus, these components exhibited interrelationship with each other.

### 5.2.2 Path coefficients analysis

**Ragi**

The wind speed had high positive direct effect of 0.5228 followed by cloudiness (0.3830) and rainfall (0.2785). The correlation between productivity of ragi and rainfall (0.5552) was high and positive followed by minimum temperature and wind speed. Hence the productivity of ragi is more depends on rainfall.

The residual value obtained was 0.7488. It indicates that 74.9 per cent of variation in the productivity of ragi was accounted by other factors; only 25% of variation in the productivity of ragi was accounted by selected seven weather parameters.

**Sugarcane**

The minimum temperature had high positive direct effect of 0.3623 followed by rainfall (0.1465) and cloudiness (0.1025) whereas maximum temperature, relative humidity, and wind speed has negative direct effect on the productivity of sugarcane. The correlation between productivity of sugarcane and rainfall (0.3113) was found to be high and positive followed by minimum temperature (0.3040). Hence the productivity of sugarcane is more dependent on rainfall and minimum temperature.

The residual variation obtained was 0.4961. It indicates that 50% of variation in the productivity of sugarcane was accounted by other factors and remaining 50% of variation in the productivity of sugarcane was accounted by selected 7 weather parameters.

### 5.2.3 Direct and indirect contribution of weather parameters on productivity of ragi

**Maximum temperature**

The direct contribution of maximum temperature on productivity of ragi was found to be 0.1179 and indirect contribution was found to be positive (0.3493) and negative (0.2204). The total contribution of maximum temperature was 0.0864. The contribution of this maximum temperature was found to be higher after cloudiness and wind speed indicating direct positive influence on the productivity of ragi.

**Minimum temperature**

The minimum temperature had a negative direct effect of -0.0595 and indirect contribution was found to be negative (0.3203) and positive (0.0513). The total contribution of minimum temperature on the productivity of ragi was found to be negative and it was -0.0153. Therefore the productivity of ragi was indirectly influenced by the minimum temperature.

**Relative humidity**

The relative humidity had a negative direct effect of -0.0933 and indirect contribution was found to be negative (0.0539) and positive (0.0994). The total contribution of relative humidity on the productivity of ragi was found to be negative and it was -0.0478. Therefore the productivity of ragi was indirectly influenced by the relative humidity.

**Cloudiness**

The direct contribution of cloudiness on productivity of ragi was found to be 0.3830 and indirect contribution was found to be negative (0.3914) and positive (0.2215). The total contribution of cloudiness was 0.2131. The contribution of this cloudiness was found to be higher after wind speed and it has direct positive influence on the productivity of ragi.

**Wind speed**

The direct contribution of wind speed on productivity of ragi was found to be 0.5228 and indirect contribution was found to be negative (0.4545) and positive (0.2887). The total contribution of wind speed was 0.3570. The contribution of this wind speed was found to be higher compared to other weather parameters and it has direct positive influence on the productivity of ragi.

**Sun shine hour**

The sun shine hour had a negative direct effect of -0.8716 and indirect contribution was found to be positive (1.1048) and negative (0.9773). The total contribution of sun shine hour on the productivity of ragi was found to be negative and it was -0.7441. Therefore the productivity of ragi was indirectly influenced by the sun shine hour.

**Rainfall**

The direct contribution of rainfall on productivity of ragi was found to be 0.2785 and indirect contribution was found to be negative (0.3823) and positive (0.0081). The total contribution of rainfall was negative and it was found to be -0.0957. The contribution of this rainfall was found to be higher after wind speed and cloudiness and it has direct positive influence on the productivity of ragi.

**Percentage contribution of weather parameters on the productivity of ragi during 1991-2010.**

The contribution of sun shine hour contribution was higher and was found to be 75.97 per cent, followed by wind speed (27.33%), cloudiness (14.67%), and rainfall (7.76%). The lowest contribution towards the productivity of ragi was minimum temperature (0.35%), relative humidity (0.87%) and maximum temperature (1.39%).

### 5.2.5 Direct and indirect contribution of weather parameters on productivity of sugarcane

**Maximum temperature**

The direct positive contribution of maximum temperature on productivity of sugarcane was found to be 0.4839 and indirect contribution was found to be positive (0.3493) and negative (0.2204). The total contribution of maximum temperature was 0.6128. The contribution of this maximum temperature was found to be higher when compared to other weather parameters and it has direct positive influence on the productivity of sugarcane.

**Minimum temperature**

The minimum temperature had a positive direct effect of 0.3623 and indirect contribution was found to be negative (0.3203) and positive (0.0513). The total contribution of minimum temperature on the productivity of sugarcane was found to be 0.0933. Therefore the productivity of sugarcane was directly influenced by the minimum temperature.

**Relative humidity**

The relative humidity had a negative direct effect of -0.3897 and indirect contribution was found to be positive (0.4155) and negative (0.2250). The total contribution of relative humidity on the productivity of sugarcane was found to be negative and it was -0.1992. Therefore the productivity of sugarcane was indirectly influenced by the relative humidity.

**Cloudiness**

The direct contribution of cloudiness on productivity of sugarcane was found to be 0.1025 and indirect contribution was found to be negative (0.1048) and positive (0.0593). The total contribution of cloudiness was 0.0570. The cloudiness has direct positive influence on the productivity of sugarcane.

**Wind speed**

The direct contribution of wind speed on productivity of sugarcane was found to be -0.1103 and indirect contribution was found to be positive (0.0959) and negative (0.0609). The total contribution of wind speed was -0.0753. Wind speed has direct negative effect on the productivity of sugarcane.

**Sun shine hour**

The sun shine hour had a positive direct effect of 0.0864 and indirect contribution was found to be negative (0.1095) and positive (0.0969). The total contribution of sun shine hour on the productivity of sugarcane was found to be positive and it was 0.0738. Therefore the productivity of sugarcane was directly influenced by the sun shine hour.

**Rainfall**

The direct contribution of rainfall on productivity of sugarcane was found to be 0.1465 and indirect contribution was found to be negative (0.2009) and positive (0.0043). The total contribution of rainfall was negative and it was found to be -0.0501. The contribution of this rainfall was found to be higher after maximum and minimum temperature and it has direct positive influence on the productivity of sugarcane.

**Percentage contribution of weather parameters on the productivity of sugarcane during 1991-2010**

The maximum temperature contribution was higher and was approximately found to be 23.42 per cent, followed by relative humidity (15.15%), minimum temperature (13.33%). The lowest contribution towards the productivity of sugarcane was sun shine hour and was found to be 0.75 per cent followed by cloudiness (1.05%), wind speed (1.22%) and rainfall (14.65%).

# VI SUMMARY

Climate change and agriculture practices are interrelated processes, both of which take place on a global scale compared to various other sectors of economy, agriculture is a unique phenomenon, whose output is largely dependent on weather conditions. The degree of success of agriculture production and its economics is determined to a large significant extent by how well weather conditions corresponding to the optimal requirements of the crop are best exploited to raise the crops. Also, how effectively adverse weather conditions, which cause moisture, thermal, wind, radiation and biotic stress impeding growth and development of crop are managed to minimize their adversity.

As such there is a need to study and understand the impact of climate changes on agriculture globally as well as at regional level. There is a lot of research and analysis going on to quantify the actual impact of climate change in each and every country. In order to mark global level scenario first step is to proceed with regional level. In this regard the present research aim is to study the trend of weather parameters and their impact on the productivity of ragi and sugarcane at Mandya district of Karnataka (Southern Dry Zone). The present study gives the suitable information regarding the climate change and its impact on crop productivity at Mandya district.

The data sets of weather parameter were used to see the climate change and its impact on productivity of ragi and sugarcane. The secondary data of weather parameters for the study was obtained from ZARS, VC Farm, Mandya for the period from 1986 to 2010. Further, the available data of crop productivity was obtained for the period from 1991-2010. The weather parameters consider viz., maximum temperature, minimum temperature, relative humidity, cloudiness, wind speed, sunshine hour, rainfall and crops yield for the study. Different statistical techniques were applied to the data sets such as descriptive statistics, trend analysis, correlation analysis, path coefficient analysis in order to study the trend and impact of weather parameters on ragi and sugarcane productivity.

**Silent features of study**

**Variability in climatic factors at Mandya district**

The more variability was found in maximum temperature, wind speed, sun shine hour and rainfall whereas less variability was noticed in minimum temperature and relative humidity and cloudiness were found to be more or less uniform over a study period of 25 years.

**Trend analysis**

The trend analysis was carried out to identify the trend pattern in the weather parameters over a study period. The results indicated that the maximum temperature shown a positive significant trend over a period of time for most of the months and linear model was found to best model to fit trend for maximum temperature whereas, the minimum temperature showed a negative non significant trend over a period of time for most of the months. Further exponential model was found to best model to fit trend for minimum temperature.

The relative humidity showing a positive non significant trend during the study period for most of the months and linear model was found to best model to fit trend for relative humidity and the cloudiness showing a negative significant trend during study period for all the months and linear model was found to be best model to fit trend for cloudiness.

The wind speed shows a negative non significant trend during study period for most of the months and the logarithmic model was found to be best model to fit trend for wind speed. The sun shine hour shown a negative significant trend during study period for all the months and the logarithmic model was found to be best model to fit trend for sun shine hour. Rainfall shown a positive non significant trend during study period for most of the months and the logarithmic model was found to be best model to fit trend for rainfall based on $R^2$ values.

**Inter relationship between ragi, sugarcane productivity and weather parameters**

The correlation analysis was carried out to know the strength of relationship between crop yield and weather parameters. It was found that the productivity of ragi was positively correlated with average minimum temperature, wind speed and rainfall, however negatively correlated with maximum temperature, relative humidity, cloudiness and sun shine hour. The sun shine hour and rainfall have significant relationship with the ragi productivity. This suggested that productivity of ragi was negatively affected by increase in the maximum temperature, relative humidity, cloudiness and sun shine hour.

The productivity of sugarcane was positively correlated with average minimum temperature, cloudiness, wind speed, sun shine hour and rainfall; however negatively and significantly correlated with maximum temperature and relative humidity. This implies that the productivity of sugarcane was negatively affected by increase in the maximum temperature and relative humidity.

**Path analysis**

1. **Productivity of ragi**

**Direct effect**

The wind speed had high positive direct effect followed by cloudiness, rainfall and maximum temperature whereas the minimum temperature, relative humidity and sun shine hour have a negative effect on the productivity of ragi. It indicates that the productivity of ragi is more depends on rainfall. The residual value obtained was 0.7488. It indicates that 75 per cent of variation in the productivity of ragi was accounted by other factors; only 25 per cent of variation in the productivity of ragi was accounted by selected seven weather parameters.

### Indirect effect

The relative humidity had a positive indirect effect and rest of the selected weather parameters had negative indirect effect on the productivity of ragi via maximum temperature. The relative humidity and rainfall have negative indirect effect and rest of the selected weather parameters have positive indirect effect on the productivity of ragi via minimum temperature.

The wind speed, sun shine hour and rainfall have a positive indirect effect and rest of the selected weather parameters had negative indirect effect on the productivity of ragi via relative humidity. The relative humidity and sun shine hour have a positive indirect effect and rest of the selected weather parameters have negative indirect effect on the productivity of ragi via cloudiness.

The sun shine hour has a positive indirect effect and rest of the selected weather parameters had negative indirect effect on the productivity of ragi via wind speed. The cloudiness and wind speed have a negative indirect effect and rest of the selected weather parameters have positive indirect effect on the productivity of ragi via sun shine hour. The minimum temperature had a positive indirect effect and rest of the selected weather parameters had negative indirect effect on the productivity of ragi via rainfall.

### Total contribution (Direct and Indirect)

The maximum temperature, cloudiness and wind speed have a positive effect and minimum temperature, relative humidity, sun shine hour and rainfall had a negative effect on the productivity of ragi in Mandya district.

### Percent contribution

The sun shine hour contribution was higher and was found to be 75.97 per cent, followed by wind speed (27.33%), cloudiness (14.67%), and rainfall (7.76%). The lowest contribution towards the productivity of ragi was minimum temperature (0.35%), relative humidity (0.87%) and maximum temperature (1.39%).

## 2. Productivity of sugarcane

### Direct effect

The minimum temperature had high positive direct effect followed by rainfall and cloudiness whereas maximum temperature, relative humidity, and wind speed had negative direct effect on the productivity of sugarcane. It indicates that the productivity of sugarcane is more depends on rainfall and minimum temperature. The residual value obtained was 0.4961. It indicates that 50 per cent of variation in the productivity of sugarcane was accounted by other factors and remaining 50 per cent of variation in the productivity of sugarcane was accounted by selected seven weather parameters.

### Indirect effect

The relative humidity has a negative indirect effect and rest of the other selected weather parameters have positive indirect effect on the productivity of sugarcane via maximum temperature. The relative humidity and rainfall had positive indirect effect and rest of the selected weather parameters had positive indirect effect on the productivity of sugarcane via minimum temperature.

The wind speed, sun shine hour and rainfall have a positive indirect effect and rest of the other selected weather parameters have negative indirect effect on the productivity of sugarcane via relative humidity. The relative humidity and sun shine hour had a positive indirect effect and rest of the selected weather parameters had negative indirect effect on the productivity of sugarcane via cloudiness.

The sun shine hour had a negative indirect effect and rest of the selected weather parameters had positive indirect effect on the productivity of sugarcane via wind speed. The cloudiness and wind speed had a positive indirect effect and rest of the selected weather parameters had negative indirect effect on the productivity of sugarcane via sun shine hour. The minimum temperature had a positive indirect effect and rest of the selected weather parameters had negative indirect effect on the productivity of sugarcane via rainfall.

### Total contribution (Direct and Indirect)

The maximum temperature, minimum temperature, cloudiness and wind speed had a positive effect; however relative humidity, sun shine hour and rainfall had a negative effect on the productivity of sugarcane in Mandya district.

### Percent contribution

The maximum temperature contribution was higher and was approximately found to be 23.42 per cent, followed by relative humidity (15.15%), minimum temperature (13.33%). The lowest contribution towards the productivity of sugarcane was sun shine hour and was found to be 0.75 per cent followed by cloudiness (1.05%), wind speed (1.22%) and rainfall (14.65%).

## Future Line of Work

For better estimation different approaches for various crops based on other variables related to weather, the following approaches can be studied for measuring the impact of yield in different crops.

- Crop info models, Simulations models etc.
- Use of atmospheric general circulation models (AGCM).
- Use of regional climatic models.

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