Influence of regional weather changes on major fruit production and productivity of Navsari district of Gujarat State, India

ABSTRACT

Horticulture is a priority sector in many states of India as it has potential to improving the socio economic condition of the farmers. Gujarat state is the fourth leading state in fruit production with 9 % share at the national level. This study is conducted to correlate major weather parameters with the production of major fruit crops of Navsari district in Southern Gujarat. The study reveals that production and productivity of 4 major fruits (banana, mango, sapota and papaya) has moderate negative correlation with mean annual temperature (MAT) i.e > -50 % except the productivity of land under banana. Whereas, it showed very weak negative and non significant relation with total annual Rainfall (TAR). Correlation of all four fruit production ranged between -34 to -53 % and -0.7 to -62 % for productivity with both MAT and TAR, respectively.

Keywords: Fruit, Weather, Area, Production, Productivity, MAT, TAR

Introduction

Global food and nutritional security is threatened by weather and climate change which is one of the most important challenges in the 21st century to supply sufficient food for the increasing population while sustaining the already stressed environment (Lal, 2005 and Kang *et al.,* 2009). Numerous studies have suggested that weather variability and climate change can have adverse impacts on global food production and food security. (Hansen *et al.*, 2011; Maxwel and Fitzpatrick, 2012; Iizumi *et al*., 2014; Iizumi –and Ramankutty, 2015). The probability of extreme weather events will reduce food production (Field *et al*., 2012; Porter *et al*., 2014). The extreme weather events are expected to affect the volatility of crop yields

and are seen as the principle immediate threat to global crop production system (Meehl *et al*., 2000) Several studies also indicated that rise in the intensity and frequency of extreme precipitation events will also reduce the crop yield (Rosenzweig *et al*., 2001; Rosenzweig *et al*., 2002; Olesen *et al*., 2007; Prasad *et al*., 2008; Urban *et al*., 2012; Min *et al*., 2011; Lobell *et al*., 2013, Kumudini *et al*., 2014; Barlow *et al*., 2015). The changes in climatic parameters have been experienced globally since last few decades resulting in affecting the crop productivity and huge loses to the farming community. The rising temperatures and erratic rainfall patterns in many Agro climatic regions of India is affecting crop production thus threatening the food and water security of poor farming community of the country (Kumar and Gautam, 2014). Situation is getting precarious as on one hand there is unchecked growth of population that has to be fed with limited resources and on the other hand there are huge losses due to floods, water scarcity and increasing temperature (Mall *et al*., 2006). Thus, there is a need to assess the impact of weather parameters on the productivity of fruit crops at the micro watershed level or district level. Gujarat state is the fifth largest producer of mango and accounts for 6% of the total production. Gujarat also stood second position in banana production in the country. Also, the state contributes major portion of ~~Sapota~~ sapota and papaya production (MIDH, 2015). The major fruit crops of South Gujarat are banana (*Musa sp*), mango (*Mangifera indica*), sapota (*Manilkara zapota*) and papaya (*Carica papaya*), further, these fruit crops are most widely cultivated in the tropics and the subtropics for its economic and nutritional values. This paper is an attempt to analyse the influence of weather on crop productivity with special reference to Navsari District of South Gujarat.

MATERIALS AND METHODS

Navsari district is situated in western coast and is in southern Gujarat. It is situated between 20°1' & 24°7' North Latitude and 68°4' to 74°4' East Longitude covering geographical area of 196 024 km^2, which is six percent of the country (MIDH 2015). The total geographical areas of Navsari district is 2657.56 Km^2 (GOI, Ministry of MSME). The state has tropical and sub - tropical climate and the weather in Navsari is sunny from September to May, and rainy from June to August. The average maximum and minimum temperatures are 40 °C and 18 °C, respectively and the mean temperature varies around 29°C. The average annual rainfall of the district is around 1600 mm. (And according to the climate classification of Köppen-Geiger?) The climate of Navsari is suitable for production of fruits like, banana, mango, sapota and papaya. Fruit production plays a crucial role in improving the economic condition of farmers of Navsari.

The present study is conducted on the basis of secondary data, from 2007 to 2017, on area, production and productivity of four major fruits in Navsari district that was collected from the Director of Horticulture, Agriculture Farmers welfare and Co-operation Department, Government of Gujarat. The data on weather parameters viz. average annual rainfall, minimum and maximum temperature was obtained from Department of Meteorology, Navsari Agricultural University, Gujarat. The compound growth rate of area, production and productivity of fruit crops were worked out using the exponential function of the form (Singh *et al*., 2014)

Comment [DAR1]: Is the data daily, monthly that has been converted to annual or is it only annual?

$$\mathbf{Y = A\ B^{X}}$$

By taking logarithm of both sides, the equation takes the form:

$$\mathbf{Log\ Y = Log\ A + X\ Lob\ B}$$

Y= Dependent variable (Area, Production and Productivity)

X= Independent variable (Time or Years)

A= Constant

B= Regression coefficient

Compound growth rate (r) = (B-1)*100

To measure the instability in area, production and productivity, coefficient of variation was used as measure of variability (Singh, 2014). The coefficient of variation (C.V.) was calculated by the formula-

Coefficient of Variation (%) = Standard deviation/ Mean X 100

The correlation between weather parameters, production and productivity was also calculated using the Karl Pearsons correlation coefficient i.e.

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sqrt{\left(\sum X^2 - \frac{(\sum X)^2}{n}\right)\left(\sum Y^2 - \frac{(\sum Y)^2}{n}\right)}}$$

where,

r = Correlation coefficient
X and Y = weather parameters, production and productivity
n = Number of observations or time in number of years

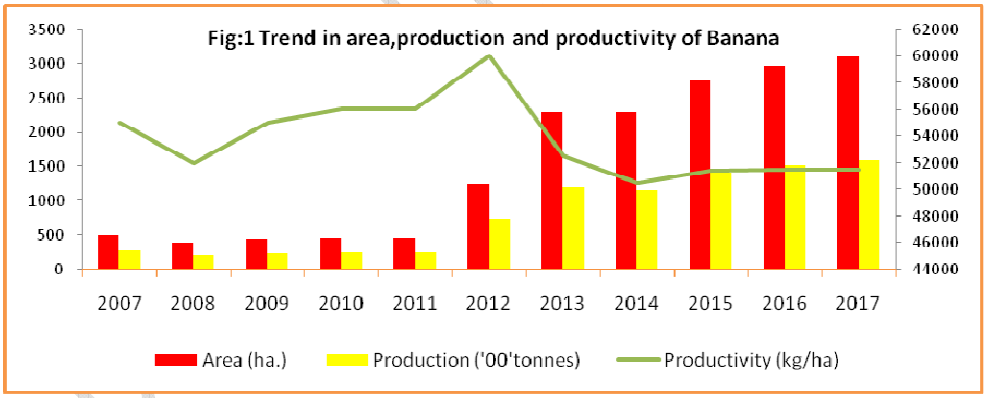
RESULTS

Growth and instability in area, production and productivity of 4 major fruits in Navsari

Trend of data on area, production and productivity of Banana, Mango, Sapota and Papaya (Sometimes you use capital letters other times lower case, please standardize.) is depicted in fig. 1-5 (Please, insert the units of measure of the vertical axes). The compound growth rates and Coefficient of Variation of area, production and productivity of banana, mango, sapota and papaya in Navsari district of Gujarat for 11 years overall worked out and presented in table 1. The study reveals that, among the four major fruits, papaya shows the significant (Papaya showed significance with what? Was Pearson's correlation test that showed significance? Please, explain better) and highest growth rate for area (11.68 % per annum), ~~Production~~ production (15.06 % per annum) and productivity (2.10 % per annum) which was followed by banana for area and production and sapota for Productivity during the study

period. In fact, the productivity of land under banana has decreased by -0.33 % per annum which is statistically non significant (The decrease in productivity per year is not statistically significant in relation to what?).

Studying only growth rates is not worth without measuring the instability because the growth rates explain only the rate of growth over the period while, instability *i.e.,* coefficient of variation judges the real fluctuation in growth performance (The coefficient of variation is a measure of the dispersion of values in relation to the mean of the analysed variable. It evidences the variability, the quality of the data without making fluctuation judgment as it is being asserted. What reference was used to affirm or to base the use of the coefficient of variation in this way?). Highest degree of instability *i.e.,* more than 70 % observed for the area and production of ~~Banana~~banana, which was followed by papaya *i.e.* 63.40 % for area and 70.20% for production. Productivity of land under the all fruit crops showing more stable growth 24.01 % for mango, 17.19 % for sapota, 15.86 % for papaya and 5.35 % for banana.



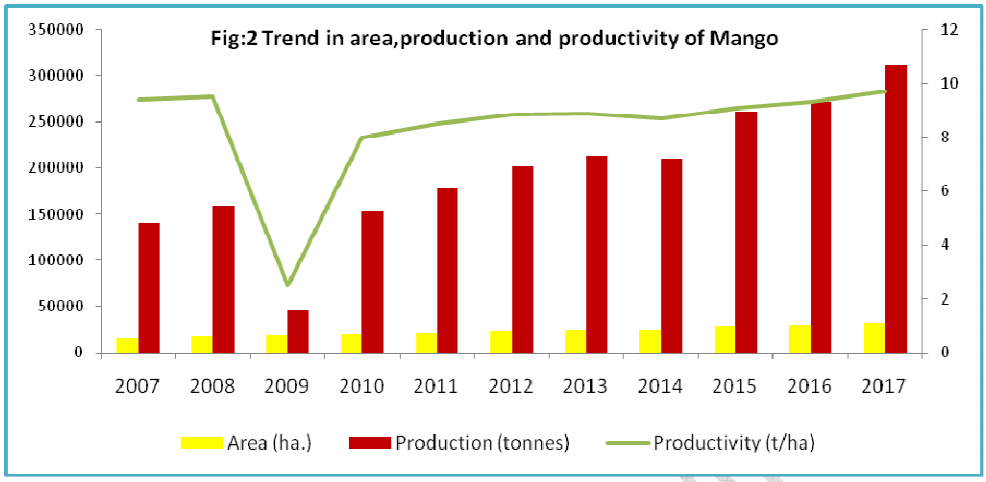


Fig:2 Trend in area,production and productivity of Mango
350000
300000
250000
200000
150000
100000
50000
0
12
10
8
6
4
2
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Area (ha.)
Production (tonnes)
Productivity (t/ha)

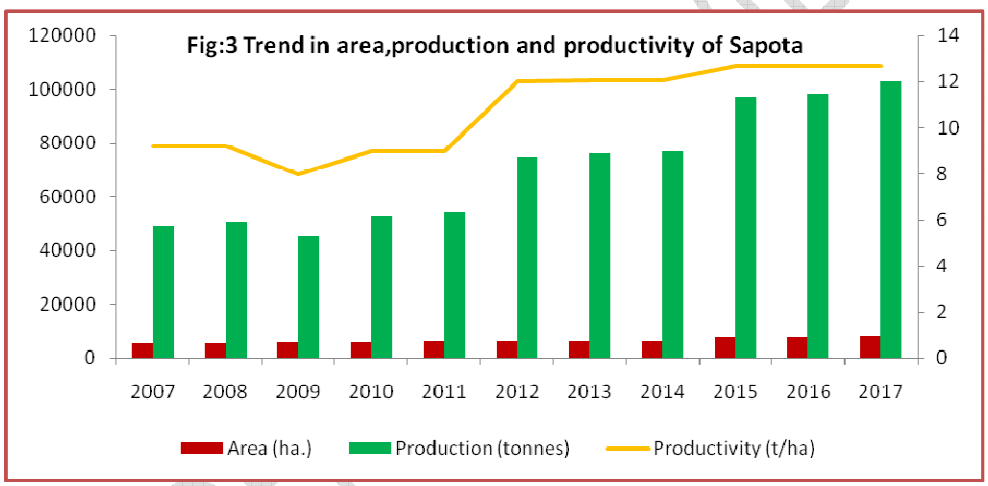


Fig:3 Trend in area,production and productivity of Sapota
120000
100000
80000
60000
40000
20000
0
14
12
10
8
6
4
2
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Area (ha.)
Production (tonnes)
Productivity (t/ha)

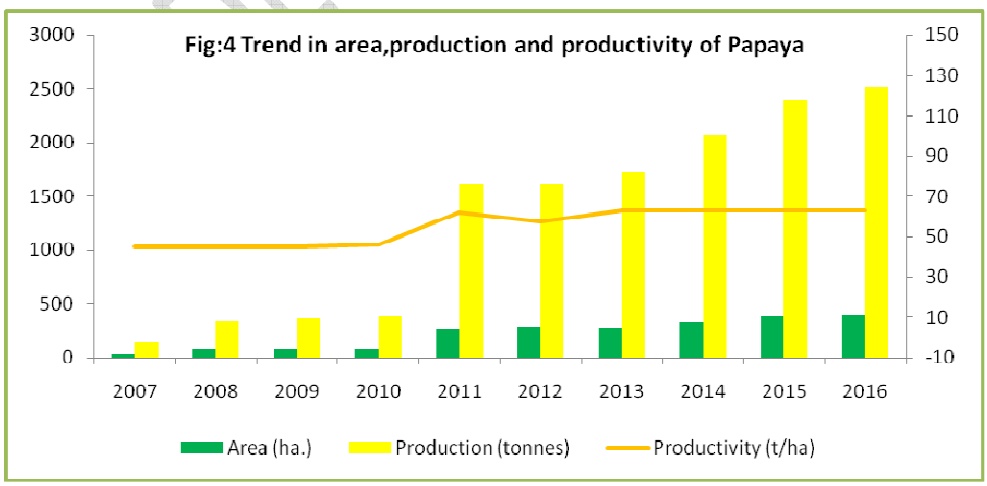


Fig:4 Trend in area,production and productivity of Papaya
3000
2500
2000
1500
1000
500
0
150
130
110
90
70
50
30
10
-10
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Area (ha.)
Production (tonnes)
Productivity (t/ha)

(Do these graphics really need to be coloured? I recommend using different geometric fills. Colours are not perceived in the same way by people.)

Table 1. Compound annual growth rate and coefficient of variation (CAGR) –for banana, mango, sapota and papaya

Crop	Area		Production		Productivity	
	CAGR (% P.A.)	Coefficient of variation (%)	CAGR (%P.A.)	Coefficient of variation (%)	CAGR (%P.A.)	Coefficient of variation (%)
Banana	11.47**	74.51	11.11**	71.87	-0.33^{NS}	5.35
Mango	3.25**	24.34	4.96*	37.54	1.65^{NS}	24.01
Sapota	1.83**	15	3.91**	30.56	2.04**	17.19
Papaya	12.68**	63.40	15.06**	70.20	2.10**	15.86

** Significance at 1 percent level and * significance at 5 percent level (Significant on which test? I did not understand the statistical procedure. Are you comparing averages? Are you just doing Correlation testing? Please explain what you are doing.)

2. Weather pattern (Mean annual temperature and Rainfall) of the region for the studied period.

Table 2 depicts the weather parameter data *i.e* Minimum temperature, Maximum Temperature, Mean Annual Temperature (MAT) and Total Annual Rainfall (TAR) (mm) for the Navsari District. Fig. 5 depicted the pattern of MAT and TAR from 2007 to 2017 for Navsari district. MAT was higher during the 2009 and 2011 which was more than 28 ^{o}C, whereas for the other studied year it was between 26 ^{o}C to 27 ^{o}C. In case of TAR, higher rainfall observed during 2013 which was more than 2442.6 mm. More or less decreasing trend of rainfall observed from 2007 to 2017. During the year 2012 and 2015 onward rainfall was less than the district average.

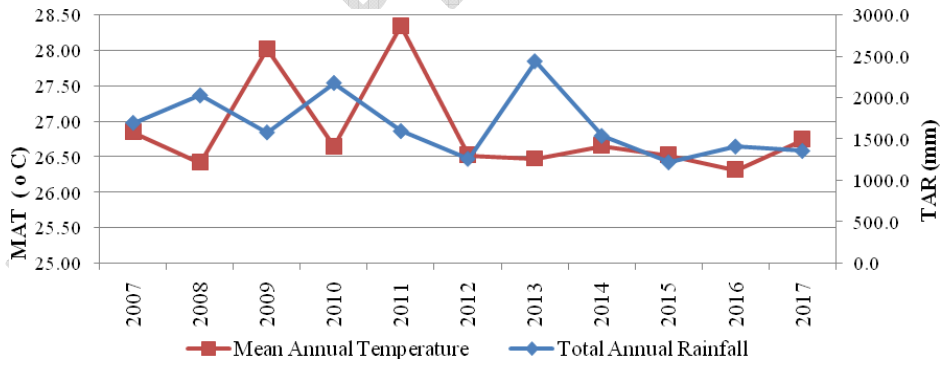
Comment [DAR2]: ???

Table-2: Annual weather parameter record of Navsari district from 2007-2017.

	Maximum	Minimum Temp.	Mean annual	Total Annual Rainfall (mm)

	Temp. (^{o}C)	(^{o}C)	temperature (^{o} C)	
2007	32.3	21.4	26.8	1696.8
2008	31.8	21.1	26.4	2030.0
2009	33.2	22.9	28.0	1582.0
2010	31.6	21.7	26.6	2180.4
2011	34.4	22.3	28.3	1597.5
2012	32.3	20.7	26.5	1262.0
2013	31.9	21.1	26.4	2442.6
2014	32.2	21.1	26.6	1539.0
2015	32.1	20.9	26.5	1219.5
2016	32.2	20.5	26.3	1411.0
2017	32.8	20.7	26.7	1358.0

Fig.5. Pattern of Mean Annual Temperature and Total Annual rainfall from 2007 to 2017



3. Correlation between rainfall, temperature, production and productivity of major fruit crops.

Table 3 representing correlation between climatic parameters such as MAT and TAR with the production and productivity of four major fruits in Navsari district. Productivity of Banana

weakly but positively correlated (33%) with the MAT (The variables evaluated in the banana presented no significant correlation) but the production was moderately negative (-50 %) with the MAT, it means the increase in temperature resulted in increasing productivity of land under banana cultivation, but on the other hand increasing temperature decreases overall production of banana (This statement cannot be made. Correlation has no significance). In case of TAR, both the production and productivity of banana negatively correlated which was about -0.37 % and -3.9%,– respectively. As the TAR increases the production and productivity of land under banana cultivation decreases (This statement cannot be made. Correlation has no significance).

Production and productivity of remaining fruits *i.e.* mango, sapota and papaya showing negative correlation with MAT and TAR. Production and productivity of mango also negatively correlated with MAT (-53% production and -61 % productivity) and with TAR (-34 % and -0.7 % respectively for production and productivity). ~~sapota~~ Sapota also shows ~~more or less~~ similar correlation as of mango *i.e* about -50 % for production and -–62 % productivity for MAT, whereas it was about -48% for production and -37% for productivity with TAR. The correlation between production of papaya with MAT and TAR was also negative i.e. 52 % and -49 %. The strength of correlation of productivity of p~~P~~apaya with MAT and TAR was also negative *i.e.* about -56 % and -53 %. In the correlation study only significant associations (P value < 0.05) were productivity of mango (-61 %) and sapota (-62%) with MAT.

Table-3 Correlation of production, productivity with mean annual temperature and total annual rainfall for major fruits of the Navsari

	Mean Annual Temperature		**Total Annual Rainfall**	
	Production	**Productivity**	**Production**	**Productivity**
Banana	-0.50 (-50%)	0.33 (33%)	-0.37 (-37%)	-0.039 (-3.9%)

Mango	-0.53 (-53%)	-0.61 (-61%) *	-0.34 (-34%)	-0.007 (-0.7%)
Sapota	-0.50 (-50%)	-0.62 (-62%) *	-0.48 (-48%)	-0.37(-37%)
Papaya	-0.52 (-52%)	-0.56 (-56%)	-0.49 (-49%)	-0.53(-53%)

Pearson Correlations *Significance at 5 percent level

DISCUSSION

According to results, production of fruit and productivity of land is negatively correlated with the temperature and rainfall, trend of correlation results are supported by the previous findings of Patil *et al.* (2015) and Salau, *et al*. (2016). Production of the fruits and productivity of land has strong negatively correlation with the temperature this is partly because some of the negative impacts of temperature change of factors like soil erosion, nutrient cycling and crop protection. Climatic warming advances both the date of the last spring frosts and the dates of flowering, and the risk of damage to flower buds caused this leads to low fruit production (Rochette *et al*., 2004). An increase in rainfall, mainly due to higher temperature and pressure and more atmospheric moisture, may result in high intensity precipitation events, causing increased soil erosion (Favis-Mortlock and Guerra, 1999), it directly affects on the productivity of land and fruit production. High rainfall associated with the flooding and the spill-over effects might also be responsible for the low fruit production and lowering productivity, this reflects negative correlation of TAR with production of fruit and productivity of land. Only the productivity of banana has weak positive correlation with temperature is exceptional result among different fruits studied.

Comment [DAR3]: The data does not support this affirmation

CONCLUSION

From above study it can be concluded that the area and production of banana, mango, sapota and papaya have been increased over the period, whereas productivity decreases over the study period. When the production and productivity of major fruit correlate with the major weather parameter like Mean Annual Temperature and Total Annual Rainfall, the association

is ranged between moderately negative to weakly positive trend. In the given correlation study, overall can be stated that only the effect MAT on the productivity of land cultivated under mango and ~~Sapota~~ sapota is notable. Otherwise all factors have very weak and negative association. Hence, the study reveals that there is very less impact of weather changes on production and productivity of major fruits of Navsari District. To establish food security, to estimate regional fruit production in future, and to examine the impacts of weather and climate change on fruit production and productivity this study must be conducted on a large scale and ~~-~~might be need to take other climatic factors in consideration~~-~~.

REFERENCES

Anonymous (2017). Horticultural Statistics at a Glance 2017, Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers Welfare, Government of India. Available at: http://nhb.gov.in/statistics/Publication/Horticulture%20At%20a%20Glance%202017%20for%20net%20uplod%20(2).pdf

Barlow,K.M., Christy,B.P.,O' Leary, G.J., Riffkin,P.A., Nuttall,J.G.(2015).Simulating the impact of extreme heat and frost events on wheat crop production: are- view. Field Crops Res.171,109–119.

Favis-Mortlock, D.T. and Guerra, A.J.T., (1999). The implications of general circulation model estimates of rainfall for future erosion: a case study from Brazil. *Catena* 37: 329–354.

Field, C., Barros, V. et al. (Eds.) (2012). Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups I and II of the intergovernmental panel on climate change, Cambridge University Press, Cambridge, UK, and New York, USA.

Goverment of India, Ministry of MSME, Brief industrial profile of NAVSARI district.

Hansen, J.W., Mason,S.J., Sun,L., Tall,A. (2011).Review of seasonal climate forecasting for agriculture in sub-Saharan Africa.Exp. Agric. 47,205–240.

Iizumi, T., Yokozawa, M., Sakurai, G., Travasso, M.I., Romanenkov, V., Oettli, P., Newby, T., Ishigooka, Y., Furuya, J. (2014). Historical changes in global yields: major cereal and legume crops from1982 to 2006. Global Ecol.Biogeogr, 23, 346–357.

Iizumi,T. and Ramankutty,N. (2015). How do weather and climate influence cropping area and intensity? Global Food Security, 4:46–50.

IPCC (Intergovernmental Panel for Climate Change). (2007a) Climate Change 2007: The fourth assessment report. impacts, adaptation and vulnerability. [https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm].

Kang, Y., Khan, S., –Xiaoyi Ma (2009). Climate change impacts on crop yield, crop water productivity and food security – A review retrieve from www.sciencedirect.com.

Kumar, R., Gautam H.R. (2014). Climate Change and its Impact on Agricultural Productivity in India. J Climatol Weather Forecasting 2: 109.

Kumudini,S., Andrade,F.H., Boote,K.J., Brown, G.A., Dzotsi,K.A., Edmeades,G.O., Gocken, T.,Goodwin,M., Halter,A.L., Hammer,G.L.,Hatfield, J.L., Jones, J.W., Kemanian,A.R.,Kim,S.-H.,Kiniry,J.,Lizaso,J.I.,Nendel,C.,Nielsen,R.L.,Parent, B., Stöckle, C.O., Tardieu,F., Thomison,P.R., Timlin,D.J., Vyn,T.J., Wallach,D., Yang,H.S.,Tollenaar,M.,(2014).Predicting maize phenology: inter comparison of functions for developmental response to temperature. Agron. J. 106, 2087–2097.

Lal R. (2005). Climate change, soil carbon dynamics, and global food security. In: Lal R, Stewart B, Uphoff N, et al., editors. Climate change and global food security. Boca Raton (FL): CRC Press; p. 113–43.

Lobell, D.B., Hammer, G.L., McLean, G., Messina, C.,Roberts, M.J.,Schlenker,W. (2013).The critical role of extreme heat for maize production in the United States.Nat.Clim.Chang.3,497–501.

Mall, R. K., Singh, R., Gupta, A., Srinivasan, G. and Rathore, L. S. (2006). Impact of Climate Change on Indian Agriculture: A Review. Climatic Change, 78: 445–478

Maxwel, D., Fitzpatrick, M. (2012). The 2011 Somalia famine: context, causes and complications. Global Food Secur1,5–12.

Meehl, G.A., Zwiers, F., Evans, J., Knutson, T., Mearns, L., Whetton, P. (2000). Trends in extreme weather and climate events: issues related to modelling extremes in projections of future climate change. Bull. Am. Meteorol. Soc. 81 (3).

Min, S.,Zhang, X., Zwiers, F.,Hegerl, G. (2011). Human contribution to more-intense precipitation extremes. Nature, 470, 378–381.

Mission for Integrated Development of Horticulture (MIDH) (2015). Joint Inspection Team (Jit) Report Gujarat-, under Horticulture Mission by Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare.

Olesen, J.E., Carter,T.R.,et al. (2007).Uncertainties in projected impacts of climate change on European agriculture and terrestrial eco systems based on scenarios from regionalclimatemodels.Clim.Chang.81,123–143.

Patil, N. A., Yeldhalli, R. A., Patil, B. O. And Tirlapur, L. N. (2015). Impact of climate change on major fruits in India, *Asian Journal of Environmental Science*, 10 (1):34-38.

Porter, J.R., Xie, L., et al. (2014). Climate change 2014: impacts, adaptation, and vul-nerability. Working Group II contribution to the IPCC Fifth Assessment Report. IPCC, authors include: Coordinating lead authors, lead authors, contributing authors and review editors.

Comment [DAR4]: It Is important to cite all authors

Prasad, P.V.V., Pisipati, S.R., Ristic, Z., Bukovnik,U., Fritz,A.K.(2008). Effect of night time temperature on physiology and growth of spring wheat.Crop.Sci.48, 2372–2380.

Rochette, P., Belanger, G., Castonguay, Y., Bootsma, A. and Mongrain, D., (2004). Climate change and winter damage to fruit trees in eastern Canada. *Can. J. Plant Sci*. 84, 1113–1125.

Rosenzweig,C., Iglesias,A.,Yang,X.B., Epstein,P.R., Chivian,E.(2001). Climate change and extreme weather events – implications for food production, plant diseases, and pests. Glob. Chang. Human Health, 2(2),90–104.

Rosenzweig, C., Tubiello, F.N., Goldberg, R., Mills, E., Bloomfield, J. (2002). Increased crop damage in the US from excess precipitation under climate change. Global Environ.Change,12,197–202.

Salau, O. R., Momoh, M., Olaleye, O.A. and Owoeye, R. S. (2016). Effects of changes in temperature, rainfall and relative humidity on Banana Production in Ondo State, Nigeria, *World Scientific News*, 44:143-154.

Singh N., Dikshit, A. K., Reddy,B. S. and Kuth,S.B.(2014). Instability in Rice Production in Gujarat: A Decomposition Analysis. Asian Journal of Economics and Empirical Research,1(1):6-9.

Singh, N.(2014). A study of integration of markets for onion and potato in South Gujarat. International Research Journal of Agricultural Economics and Statistics, 5(2):241-244.

Urban,D.,Roberts,M.J.,Schlenker,W.,Lobell,D.B.(2012). Projected temperature changes indicate significant increase in inter-annual variability of U.S. maize yields. Clim. Chang.112(2),525–533.