RESEARCH ARTICLE

Impact of Drought on Groundnut Productivity Over Tamil Nadu

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ABSTRACT

Globally, agriculture is highly dependent on climate and weather. The deviation from the normal weather including drought, flood, heat waves and cold waves affects all the sectors in particular agriculture sector. Droughts in India are mainly due to failures of seasonal rainfall. Rainfall is one of the most important weather variables that has been influencing the crop growth and yield. Rainfall variability proves to be an influential factor in the yield component of a crop. As Tamil Nadu is located in the tropical climatic condition, the crops productivity is mainly limited by water availability. For the rainfed situation, only source of moisture for crop production is rainfall. Hence, when there is normal or above normal rainfall with even distribution, it leads to increased crop productivity. Simulation models are the most reliable tool for assessing drought on crop production and determine drought stress patterns on crops. CROPGRO-Groundnut model embedded in DSSAT 4.6 was employed to simulate the productivity of groundnut for 37 years (1981-2017) that is grown between June to September in Tamil Nadu and productivity was compared between Deficit, Normal and Excess rainfall years. The results revealed that the average yield of rainfed groundnut was greater for Excess rainfall years (2166 kg ha^{-1}) followed by normal (1772 kg ha^{-1}) and deficit years (1161 kg ha^{-1}). The coefficient of variation in groundnut productivity was high during deficit (10 %) years compared to excess (5 %) and normal (3 %) years.

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INTRODUCTION

Agriculture is highly dependent on climate and weather globally. Changes in temperature, precipitation, and other weather patterns can have significant impacts on crop yields, water availability, and overall agricultural productivity. This makes the agriculture sector particularly vulnerable to the effects of climate change. India has been a frequent victim of such disasters, which has resulted in huge loss of natural resources. In many parts of India, drought is a perennial and recurring feature, and become single natural cause of Indian famines in the past. Droughts in India are mainly due to failures of seasonal rainfall. Rainfall is one of the most important weather variables that has been influencing the crop growth and yield. Rainfall variability proves to be an influential factor in the yield component of crop. Tamil Nadu, situated in a tropical climate, faces challenges with water availability, which significantly impacts crop productivity. In rainfed situations, crop production relies solely on rainfall for moisture. Adequate and well-distributed rainfall enhances crop productivity. However, Tamil Nadu experiences regular droughts, impacting agricultural output. Efficient water management is crucial for sustaining and improving crop productivity in the region. The state benefits from NEM rainfall during the months of October to December and receives about 48 per cent of its annual rainfall unlike other regions of India (Nathan, 1995). Coastal district of Tamil Nadu receives 60 per cent, while inland districts receive 40-50 per cent of their annual rainfall during North East monsoon period (De and Mukhopadhyay 1999). Several studies have been conducted for quantification of drought whereas assessment of production loss due to the agricultural drought is very limited. There is a need for efficient method to monitor the yield loss under drought stress (Zipper *et al.,* 2016). Groundnut, also known as *Arachis hypogaea L.,* is a significant oil seed crop in India, contributing to approximately 30% of the country's domestic vegetable oil supply. groundnuts are primarily grown under rainfed conditions. The main challenges in production include abiotic stresses such as drought and wet spells (Srinivas, 2016).

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Simulation models are robust tools to guide our understanding of how a system responds to a given set of conditions and also a valuable tool for assessing drought on crop production and determine drought stress patterns on crops (Kurniasih, 2017). Environmental impacts were evaluated by Crop Simulation Model to quantify the yield gap between the potential yield and actual yields and provide a unique means of quantifying the potential impacts of drought on crop performance (Rajasivaranjan, 2015). International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) has integrated the process oriented dynamic crop simulation models into a single computer software package known as DSSAT (Decision Support System for Agrotechnology Transfer), is developed through the internationally collaboration work carried out under IBSNAT, U.S.A., across the globe (Jones *et al.,* 2003). DSSAT integrates the soil, crop phenotype, weather and management options to simulate crop growth and development and to predict crop yield. Crop model require daily minimum and maximum air temperatures, precipitation and solar radiation, in addition to the crop management data (such as planting date, seed cultivar, soil type and nutrient loading). The output is end-of-season crop yield as well as nutrient, soil moisture and plant stress variables (Jones *et al.,* 2003). Crop simulation models have been evaluated and used for many soil and environmental conditions across the world and have been successfully used in yield predictions (Jagtap and Jones 2002).

MATERIAL AND METHODS

Description of the study area

Tamil Nadu is located in the Southernmost tip of the Indian Peninsula between 8°5' and 13°35' North latitude and 76°15' and 80°20' East longitude with 960 km coastline that helps in moderating the summer and winter temperatures, occupying 7 % of the India's population, 4 % of the land area and 3 % of the water resources.

Historic climate data source

ECMWF reanalysis Interim (ERA-I) data available at a 0.75° horizontal resolution (Dee *et al.,* 2011) was used as initial and boundary conditions in WRF model. All available satellite and in-situ observations in the region were assimilated into WRF using the consecutive re-initialization method as described by (Langodan *et al.,* 2016 and Viswanadhapalli *et al.,* 2017) to generate the data over a 37-year period (1981-2017) .

Impact of drought on Groundnut productivity

In the present study, CROPGRO - Groundnut embedded in DSSAT 4.7 was employed to simulate the productivity of the respective crops for 37 years (1981-2017) and the resultant yield was related with drought episodes.

Simulation of crop yield using DSSAT model

The Decision Support System for Agro-technology Transfer (DSSAT) is a micro-computer software product that combines crop, soil and weather data-bases into standard formats for access by crop models and application programs. The user can then simulate multi-year outcomes of crop management strategies for different crops for any location in the world (Hoogenboom *et al.,* 2010) and hence the DSSAT was used in the present investigation.

Weather file

The daily weather data on maximum temperature (°C), minimum temperature (°C) and rainfall (mm) solar radiation (MJ/m^2/day) wind speed (km/hr) and relative humidity (%) for the period of 37 years (1981-2017) for the concerned district were converted into DSSAT weather file using 'Weatherman' tool available in DSSAT. The collected data was quality checked and used for simulation.

Soil data file

Soil information for creating the soil files was obtained from the Department of Remote Sensing and Geographical Information System, TNAU. The profile details as required in DSSAT are extracted from the above remote sensing database using ArcGIS and were fed into S-Build tool in DSSAT to create soil file.

Experimental detail file

Crop management practice followed during the field experiments were recorded and input in to 'X Build' tool in DSSAT. The details of experimental conditions and field characteristics such as weather station name, soil, and field description details, initial soil, water and inorganic nitrogen conditions, planting geometries, water management, fertilizer management details, organic residue application, chemical applications, tillage operations, environmental modifications, harvest management and simulation controls (specification of simulation options e.g. starting dates, on/off options for water and nitrogen balances, symbiosis) and output options are given in the experimental file.

Genetic co-efficient

Farmers change the cultivars based on their requirement and suitability for their location, in order to maximize yield. The DSSAT crop models also have the ability to take this source of variability into account. For each crop simulation model, the cultivars are characterized by a specific set of genetic coefficients and these coefficients express the genetic potential of each genotype independently of all environmental constraints like soil, weather, etc. Model calibration or parameterization is the adjustment of genetic parameters so that simulated values compare well with observed values. Data obtained from the experiments were used to estimate genetic parameters.

CROPGRO - Groundnut embedded in DSSAT model was calibrated for groundnut cultivar VRI 2.

VRI 2	CSDL	PPSEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LFMAX	SLAVR
	11.84	0	14	9	16	58	78	1.65	273
	SIZLF	XFRT	WTPSD	SFDUR	SDPDV	PODUR	THRSH	SDPRO	SDLIP
	18	0.83	1.03	31	2	15	85	0.27	0.51

Output Files

The output file generated by the model runs gives an overview of input conditions, crop performance and yield. Outputs from the model are used for understanding drought influence on productivity of maize, groundnut and cotton across the districts in Tamil Nadu except Chennai and Nilgiris

RESULTS AND DISCUSSION

The impact of drought conditions on groundnut productivity is presented in Table 1. Groundnut productivity was compared between Deficit, Normal and Excess years.

The simulations conducted with the CROPCRO-groundnut model for 37 years of weather data for Tamil Nadu revealed that the average yield of rainfed groundnut was greater for Excess rainfall years (2166 kg ha^{-1}) followed by normal (1772 kg ha^{-1}) and deficit years (1161 kg ha^{-1}). Highest yield was noticed for excess rainfall years was 2375 kg ha^{-1}, for normal year's 1837 kg ha^{-1} and for deficit years (1549 kg ha^{-1}). The least in the category of excess rainfall years was observed 1941 kg ha^{-1}, while for normal year recorded 1667 kg ha^{-1} and deficit years registered 854 kg ha^{-1}. The coefficient of variation in groundnut productivity was high during deficit (10 %) years compared to excess (5 %) and normal (3 %) years. Simulation results from DSSAT model gave 1722 kg ha^{-1} under normal rainfall years, whereas, the yield level got enhanced to 2166 kg ha^{-1} under excess rainfall years and got declined to 1161 kg ha^{-1} in deficit years for Groundnut (Figure 1).

In most parts of Tamil Nadu higher crop productivity was noticed under excess rainfall situation and lesser productivity observed under deficit condition. As Tamil Nadu is located in the tropical climatic condition, the crops productivity is mainly limited by water availability. For the rainfed situation, only source of moisture for crop production is rainfall. Hence, if the rainfall is normal or above normal with good distribution, crops productivity is enhanced. These observations are in corroboration with the findings of Kurniasih (2017) who studied maize yield variability impacted by drought. The best years of maize production happened when the drought index doesn't indicate a drought event and vice-versa. The worst year of maize production occurs when the drought index indicates the incidence of droughts. Yu *et al.,* (2014) reported during the drought years the drought induced yield loss was noticed in Liaoning province, china.

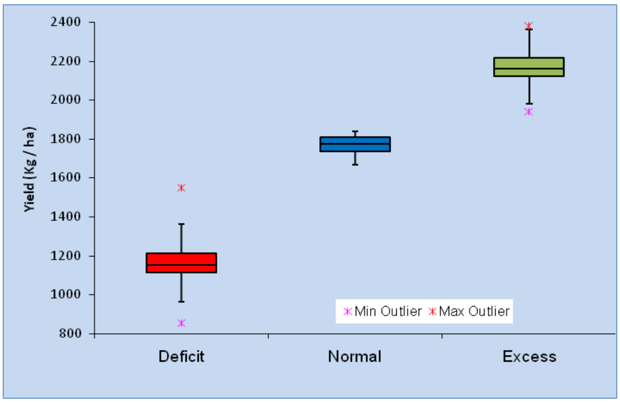

Figure 1. Effect of varied climate on Groundnut productivity

Table 1. Impact of drought on groundnut productivity (kg/ha)

District	Deficit	Normal	Excess
Ariyalur	1155	1837	2246
Coimbatore	1125	1826	2211
Cuddalore	1235	1734	2216
Dharmapuri	1120	1699	2152
Dindigul	1101	1836	2171
Erode	1107	1776	2250
Kancheepuram	1163	1751	2187
Kanniyakumari	1297	1784	2022
Karur	1266	1811	2273
Krishnagiri	1285	1770	2083
Madurai	1116	1782	2132
Nagapattinam	1133	1808	2310
Namakkal	1210	1712	2309
Perambalur	1148	1735	2104
Pudukkottai	1238	1774	2219
Ramanathapuram	1208	1821	2151
Salem	1103	1824	2208
Sivaganga	1213	1769	2149
Thanjavur	1236	1813	2198
Theni	1181	1708	2063
Thiruvallur	1549	1786	2122
Thiruvarur	951	1783	2375
Thoothukkudi	1133	1791	2124
Tiruchirappalli	1062	1837	2188
Tirunelveli	1111	1724	1941
Tiruppur	854	1667	1970
Tiruvannamalai	1141	1768	2135
Vellore	1083	1735	2133
Viluppuram	1155	1743	2264
Virudhunagar	1161	1770	2060
Average	1161	1772	2166
SD	117	45	98
CV	10	3	5

Conclusion

This observation is consistent with the general understanding that crops require adequate water for optimal growth and productivity. In excess rainfall years, the crops have access to sufficient moisture, which promotes their growth and development. On the other hand, under deficit rainfall conditions, the crops face water stress, which hampers their growth and productivity. Overall, the observed higher productivity of rainfed crops under excess rainfall years and lower productivity under deficit conditions highlights the critical role of water availability in agricultural productivity and the need for effective water management strategies in rainfed regions.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

Data availability

All the data of this manuscript are included in the MS. No separate external data source is required. If anything is required from the MS, certainly, this will be extended by communicating with the corresponding author through corresponding official mail; vengateswariagmet@gmail.com

Author contributions

Research grant-DST, Idea conceptualization-MV,VG Experiments- MV,SA,CD Guidance -VG,KB Writing original draft – MV, KB Writing- reviewing & editing - MV, PJ.

REFERENCES

De, US, and Mukhopadhyay, RK. 1999. The effect of ENSO/Anti ENSO on northeast monsoon rainfall. *Mausam.,* **50** (4), 343-354. doi.org/10.54302/mausam.v50i4.1947.

Dee, Dick P, SM Uppala, AJ Simmons, Paul Berrisford, P Poli, S Kobayashi, U Andrae, MA Balmaseda, G Balsamo, and Bauer, d P. 2011. "he ERA-Interim reanalysis: Configuration and performance of the data assimilation system. *Quarterly Journal of the royal meteorological society.,* **137 (656),** 553-597. DOI:10.1002/qj.828

Hoogenboom, G, JW Jones, PW Wilkens, CH Porter, KJ Boote, LA Hunt, U Singh, JL Lizaso, JW White, and Uryasev, O. 2010. Decision support system for agrotechnology transfer (DSSAT) version 4.5. *Honolulu: University of Hawaii.,* **1**.

Jagtap, Shrikant S, and James W Jones. 2002. Adaptation and evaluation of the CROPGRO-soybean model to predict regional yield and production. *Agriculture, ecosystems & environment.,* **93 (1-3),** 73-85. doi.org/10.1016/S0167-8809(01)00358-9.

Jones, James W, Gerrit Hoogenboom, Cheryl H Porter, Ken J Boote, William D Batchelor, LA Hunt, Paul W Wilkens, Upendra Singh, Arjan J Gijsman, and Joe T Ritchie. 2003. The DSSAT cropping system model. *European journal of agronomy.,* **18 (3-4),** 235-265. DOI:10.1016/S1161-0301(02)00107-7

Kurniasih, E. 2017. Use of Drought Index and Crop Modelling for Drought Impacts Analysis on Maize (Zea mays L.) Yield Loss in Bandung District. IOP Conference Series: Earth and Environmental Science. DOI 10.1088/1755-1315/58/1/012036.

Langodan, Sabique, Yesubabu Viswanadhapalli, Hari Prasad Dasari, Omar Knio, and Ibrahim Hoteit. 2016. A high-resolution assessment of wind and wave energy potentials in the Red Sea. *Applied energy.,* **181,** 244-255. DOI: 10.1016/j.apenergy.2016.08.076.

Nathan, KK. 1995. Assessment of recent droughts in Tamil Nadu. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1057&context=droughtnetnews.

Rajasivaranjan, T. 2015. Crop specific drought monitoring and yield loss assesssment by integrating geospatial, climate and crop modelling. Technology in Remote Sensing and Geographic Information System, Andhara University.

Srinivas, T. (2016). Assesment of genetic diversity for kernel yield and quantitative traits in drought tolerant groundnut genotypes. *Electronic Journal of Plant Breeding*, **7**(1), 29-36. DOI : 10.5958/0975-928X.2016.00004.1

Viswanadhapalli, Yesubabu, Hari Prasad Dasari, Sabique Langodan, Venkata Srinivas Challa, and Ibrahim Hoteit. 2017. Climatic features of the Red Sea from a regional assimilative model. *International Journal of Climatology.,* **37 (5),** 2563-2581. **doi.org/10.1002/joc.4865**.

Yu, Chaoqing, Changsheng Li, Qinchuan Xin, Han Chen, Jie Zhang, Feng Zhang, Xuecao Li, Nick Clinton, Xiao Huang, and Yali Yue. 2014. Dynamic assessment of the impact of drought on agricultural yield and scale-dependent return periods over large geographic regions. *Environmental modelling & software.,* **62,** 454-464. https://doi.org/10.1016/j.envsoft.2014.08.004.

Zipper, Samuel C, Jiangxiao Qiu, and Christopher J Kucharik. 2016. Drought effects on US maize and soybean production: spatiotemporal patterns and historical changes. *Environmental research letters.,* **11 (9),** 094021. **DOI** 10.1088/1748-9326/11/9/094021