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Short Communication

Projected climate changes and environment suitability of foot yam in major growing areas of India

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ABSTRACT

The projected climatic changes were in the major elephant foot yam growing environments of India which were identified based on expert knowledge and from literature review; and also calibrated and evaluated the EcoCrop model, of FAO to study the impact of 2030 climate the suitability of elephant foot yam in the major growing environments of India. The current and future climatic projections of 22 Global Circulation models from the SRES-A1B emission scenario were used for the study. A total of 9345 unique coordinates, as points was obtained as elephant foot yam presence points in India. The projected change in annual mean temperature and total annual precipitation in the major growing areas ranged from 0.9 to 1.2^{0}C and from 19 to 68 mm respectively. The calibrated data were used to drive the EcoCrop model to find out the suitability of current and future climatic conditions. The change in suitability for all the 22 GCMs used was calculated on pixel basis and the mean suitability change indicate that elephant foot yam is actually positively impacted in the current growing areas of India with 0.8 to 9.6% changes in climate suitability. The overall suitability change in the major elephant foot yam growing areas showed that the crop is potentially highly resilient to future climatic changes.

Key words: *Amorphophallus paeoniifolius*, temperature, participation, EcoCrop.

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is a tropical tuber crop that offers excellent scope for adoption in the tropical countries as a cash crop due to its production potential and popularity as a vegetable in various delicious cuisines. It is a crop of southeast Asian origin, and grows in wild form in the Philippines, Malaysia, Indonesia and south-east Asian countries. It is considered as a famine food in the Pacific Islands. It is becoming very much popular in different parts of India due to its palatability and better cooking quality (Srinivas and Ramanathan, 6; Venkatesan *et al*., 7). There are different studies that quantified the impact of climate change on different crops and also on tuber crops like cassava, yams and sweet potato using different crop growth models like GEPIC, EcoCrop etc. Jarvis *et al*. (4) studied the impact of 2030 climate on cassava and other staple food crops like maize, millets, sorghum, banana and beans of Africa using EcoCrop model. Mijiyawa *et al*. (5) analyzed the climatic and crop yield data using correlation analytical techniques, multiple regression and trend analysis in order to evaluate the impact of climate on the yield of the most important tuber crops in Kwara State, Nigeria viz: cassava, yam, and sweet potato. The study of the impact of climate change on root crops is crucial because these food crops are vital to the rural poor and are a cash crop in several countries. The aim of present study was to develop an elephant foot yam (EFY) presence point map based on expert knowledge, to assess what are the projected climatic changes in EFY growing areas of India, to calibrate the EcoCrop model and to model the suitability of current EFY growing areas and to study the impact of future climate (2030 climate) on climate suitability of EFY in India.

Current and future climate data were downloaded from the WorldClim dataset (Hijmans *et al*., 2), freely available for download from the website http://www.WorldClim.org. The data downloaded for this study was at the resolution of 30 arc-seconds, restricted to India. The data downloaded were the monthly time series of maximum, minimum and mean temperature and total monthly precipitation for SRES-A1B emission scenarios of the 21st century simulations from 22 different coupled global climate models (GCMs) used in the IPCC Fourth Assessment Report (IPCC, 3) for the period 2030s (2020-2049), centred in 2035. Change in climate was calculated by subtracting the current climate grid of India from the future climate grid. The GCM specific changes in total annual precipitation and annual mean temperature were extracted for the EFY growing regions in India for further analysis. The basic mechanistic model (EcoCrop) we implemented uses environmental ranges as inputs to determine the main niche of a crop and then produces a suitability index as output.

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The calibration of EcoCrop model for EFY was done following the procedure given by Villegas *et al*. (8). Crop suitability modeling involved the evaluation of the model and the usage of the selected ecological parameter set(s) to run the model using certain climate scenario(s). All the suitability analysis was carried out by using DivaGIS and ArcGIS softwares. For each projection, the change in suitability was calculated on a pixel basis and the following impact matrices were derived for EFY growing regions for each GCM specific predictions.

a. The overall suitability change (average % change of all pixels)
b. The average suitability change in positively impacted areas (ie., areas increasing suitability)
c. The average suitability change in negatively impacted areas (ie., areas decreasing suitability)

Out of the 22 GCMs studied, only one GCM *viz*. MRI-CGCM2.3.2A predicted that the temperature will remain stable or reduce in some of the current EFY growing areas with annual mean temperature change from -0.5 (Jharkhand) to +0.3º C (Kerala). A maximum increase of 1.7º C was predicted by different GCMs for Bihar (GFDL-CM2.1 and GISS-MODEL-EH), Jharkhand (GISS-MODEL-EH and GISS-MODEL-ER) and Gujarat (MIROC3.2-HIRES). The highest and lowest mean temperature changes for Kerala (+1.4 to 0.3º C) was predicted by the GCMs, MIROC3.2-HIRES and MRI-CGCM2.3.2A respectively. An increase in annual mean temperature of 1.3º C for Andhra Pradesh was predicted by two GCMs viz. INM-CM3.0 and IPSL-CM4 and the lowest increase of 0.2º C was predicted by MRI-CGCM2.3.2A. For West Bengal, the highest and lowest changes in annual mean temperature (+1.5 to -0.2º C) were predicted by the GCMs GISS-MODEL-ER and MRI-CGCM2.3.2A respectively.

The average of the 22 different GCMs under the SRES A1B emission scenario showed that by 2030, all the major EFY growing states in India will have an increase in their annual mean temperature and the predicted increase ranged between 0.9 and 1.2º C. Out of the 50 districts selected as current growing areas of EFY, about 40% of districts showed an increase in annual mean temperature of 0.9º C, 28% districts showed 1º C increase, 18% districts showed 1.1º C increase and the remaining 14% districts showed 1.2º C increase in annual mean temperature. The highest increase was observed in the Gumla district of Jharkhand (1.3º C). For the major EFY producing states of Andhra Pradesh, Kerala, and West Bengal, the change in annual mean temperature ranged from 0.9 to 1.1º C 0.9 to 1.0º C and 0.9 to 1.1º C respectively. In other growing areas, the mean increase in temperature was 1.1º C for Bihar, 1.2º C for Gujarat and Jharkhand, 1.0º C for Karnataka and 0.9º C for Tamil Nadu.

Out of the 22 GCMs studied, three GCMs viz. CCCMA-CGCM3.1 (T47), NCAR-CCSM3.0 and UKMO-HADCM3 predicted an increase in total annual precipitation in all the EFY growing states with a range of 44 (Tamil Nadu) to 235 mm (Andhra Pradesh), from 6 (West Bengal) to 153 mm (Jharkhand) and from 41(Karnataka) to 124 mm (Andhra Pradesh) respectively. The GCM, IAP-FGOALS1.0-G predicted that by 2030 all the EFY growing states will experience a decrease in total annual precipitation with values ranging from -129 (Kerala) to -24 mm (Jharkhand) and the remaining GCMs showed varying precipitation changes. The highest annual precipitation increase was observed for Bihar ranging from 88 to 380 mm with mean value of 241 mm showed by the GCM 'GFDL-CM2.0'.

The average of the 22 GCMs showed that by 2030 all the major EFY growing states will have an increase in total annual precipitation with values ranging from 19 (Andhra Pradesh) to 68 mm (Tamil Nadu). In the major growing areas of Andhra Pradesh, Kerala and West Bengal, the annual precipitation increase ranged from 12 to 19 mm, 5 to 51 mm and 17 to 33 mm respectively. The increase of total annual precipitation in other growing areas ranged from 12 to 19 mm for Bihar, 20 to 22 mm for Gujarat, 17 to 29 mm for Jharkhand, 15 to 30 mm for Karnataka and 5 to 68 mm for Tamil Nadu. Predicted changes (average of 22 GCMs) in annual precipitation for the major EFY growing districts ranged between 10 and 57 mm/year with the minimum increase in the Wayanad district of Kerala (10 mm) and the maximum increase was observed in the Pashchim Champaran district of Bihar (57 mm).

The current suitability of the EFY growing regions was studied using the calibrated ecological parameters in EcoCrop. According to the EcoCrop model, highly sui areas for growing EFY (> 80 %) were predicted to be located in the states of Andhra Pradesh, Gujarat, Kerala, Karnataka, Tamil Nadu and West Bengal, matching the known distribution of the crop. All the areas selected as EFY presence points showed a suitability of above 60 per cent by EcoCrop model. The current suitability prediction showed that the suitability of all districts in Kerala ranged from 60 to 100%. The East Godavari and West Godavari districts of Andhra Pradesh showed 80 to 100% suitability. Almost all the districts selected as EFY growing regions in West Bengal showed a suitability range of 80 to 100%. A suitability range of below 40% was observed in the northern and northeastern states of India which are not major growing areas of elephant foot yam.

The future predictions on EFY climatic suitability showed that, on an average, EFY production in India is favored by climate change or there are not much decrease in climatic suitability of EFY by 2030 (Fig. 1). The future suitability predictions in the major EFY growing areas were almost similar as in the current suitability predictions. In the states of Andhra Pradesh, Kerala, Gujarat, Jharkhand and Tamil Nadu, the future suitability percentage is almost similar as in the current condition. A little increase in suitability for growing EFY by 2030 was observed in some districts of Bihar, Karnataka and West Bengal. Almost all the districts in West Bengal showed 80 to 100% suitability for growing EFY in future. In the state of Bihar, the current suitability for all the districts was in the range of 60 to 80%, whereas in future some districts showed increase in their suitability from 80 to 100%.

The individual GCM predicted changes in suitability is presented in Table 1. The overall suitability change in the EFY growing regions ranged between -5.3 (MRI-CGCM2.3.2A) and 12.0 % (NCAR-PCM1) with suitability change in positively and negatively impacted areas ranged from 5.0 (IAP-FGOALS1.0-G) to 19.8 % (NCAR-PCM1) and from -28.9 (IAP-FGOALS1.0-G) to -2.9 % (UKMO-HADCM3) respectively. Only one GCM viz., MRI-CGCM2.3.2A predicted a decrease in suitability for EFY in the major growing areas of India. All other GCMs predicted an increase in suitability ranging from 0.7 to 12.0 % for all the EFY growing areas by 2030. In the case of Andhra Pradesh, Kerala and West Bengal, where majority of the EFY area is located in India, only one GCM, 'MRI-CGCM2.3.2A' predicted a negative suitability change for Andhra Pradesh (-1.1), seven GCMs viz., CCCMA-CGCM3.1 (T47), CCMA-CGCM3.1 (T63), CNRM-CM3, CSIRO-MK3.0, MIROC3.2-HIRES, MIROC3.2-MEDRES and NCAR-CCSM3.0 predicted negative suitability change for Kerala ranging from -8.5 to -0.4%, for West Bengal, three GCMs viz., MRI-CGCM2.3.2A, MPI-ECHAM5 and CCCMA-CGCM3.1 (T47) predicted negative suitability change ranging from -9.8 to -0.9% and the remaining predicted a positive suitability change for these three states.

The overall suitability changes in all the EFY growing states ranged from 0.8 (Kerala) to 9.6 % (Jharkhand). The change in suitability from current to future climatic conditions showed that there are no severe impacts for EFY suitability by 2030. The predicted increase in suitability for the major growing states was observed to be 9.6 % for Jharkhand, for

Table 1. Regional changes in EFY suitability for individual GCMs.

GCM	OSC*	SCPIA*	SCNIA*
CCCMA-CGCM3.1 (T47)	2.3	9	-4.6
CCMA-CGCM3.1 (T63)	5.6	11	-13.8
CNRM-CM3	2.3	6.9	-5.5
CSIRO-MK3.0	6.1	9.5	-5.2
CSIRO-MK3.5	6.3	9.5	-5
GFDL-CM2.0	6.8	10.9	-12.9
GFDL-CM2.1	8.6	12	-4
GISS-AOM	6.5	9.8	-5.2
GISS-MODEL-EH	8.9	12.1	-4.6
GISS-MODEL-ER	5.9	10.2	-6.6
IAP-FGOALS1.0-G	1.2	5	-28.9
INGV-ECHAM4	5.9	9.8	-14.4
INM-CM3.0	8.9	12.3	-3.7
IPSL-CM4	4.8	8	-6.6
MIROC3.2-HIRES	8.7	14.4	-9.7
MIROC3.2-MEDRES	4.6	10.3	-16.3
MPI-ECHAM5	0.7	5.9	-4.2
MRI-CGCM2.3.2A	-5.3	6.4	-9.3
NCAR-CCSM3.0	10.9	16.7	-8.5
NCAR-PCM1	12	19.8	-4.2
UKMO-HADCM3	5.7	9.5	-2.9
UKMO-HADGEM1	3.6	8.4	-19.4

OSC* - overall suitability change, SCPIA*- suitability change in positively impacted area, SCNIA*- suitability change in negatively impacted area

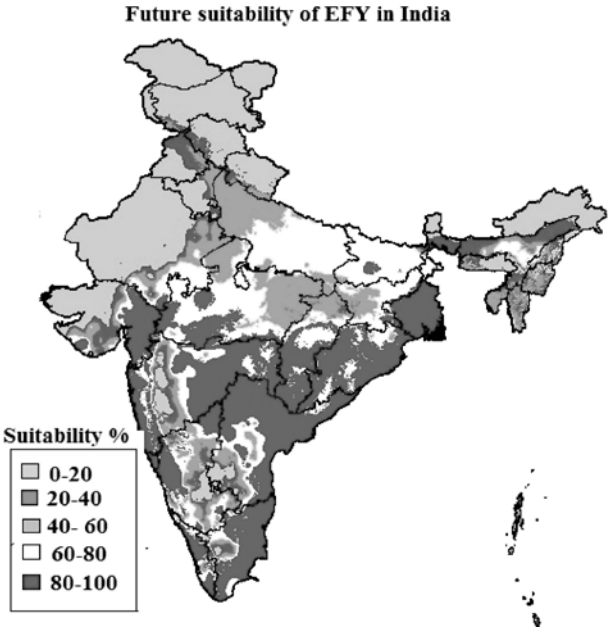

Fig. 1. Future suitability of EFY (average of 22 GCMs) in India predicted by EcoCrop model

Gujarat 8.8 % increase in suitability, for West Bengal 7.1 % increase, for Tamil Nadu 6.4 % increase, for Bihar 6.3 % increase, for Karnataka 4.8 % increase, for Andhra Pradesh 1.6 % increase, for Kerala 0.8 % increase. The average of the 22 GCMs showed that the overall suitability change of all the major EFY growing states are positive indicating the increase in suitability of EFY in future climatic conditions. Different authors reported the beneficial characteristics and resilience of other tuber crops like cassava in the context of climate change (Ceballos *et al*., 1; Jarvis *et al.,* 4).

The changes in annual mean temperature ranged between 0.9 and 1.2ºC. The highest increase was observed in the Gumla district of Jharkhand (1.3ºC). According to the prediction of the average of 22 GCMs, the major EFY producing states like Andhra Pradesh, Kerala, and West Bengal, the change in annual mean temperature ranged from 0.9 to 1.1ºC 0.9 to 1.0ºC and 0.9 to 1.1ºC respectively. The change in total annual precipitation ranged from 19 (Andhra Pradesh) to 68 mm (Tamil Nadu). In the major growing states like Andhra Pradesh, Kerala and West Bengal, the annual precipitation increase ranged from 12 to 19 mm, 5 to 51 mm and 17 to 33 mm respectively. The minimum increase in precipitation was observed in the Wayanad district of Kerala (10 mm) and the maximum increase was observed in the Pashchim Champaran district of Bihar (57 mm).

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