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Research Paper

Future climate suitability of underutilized tropical tuber crops-'Aroids' in India

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ABSTRACT

Elephant foot yam and taro are the two important aroids of tropical tuber crops, considered as underutilized in the context of climate change and food security. The present study focused to quantify the future climate suitability of aroids for future climate scenarios 2030, 2050, and 2070 for the two representative concentration pathways (RCP 4.5 and RCP 8.5). The district-wise future climate suitability of elephant foot yam and taro using MaxEnt across India is quantified. The percentage increase in climatically suitable area for taro is 49% and the same for elephant foot yam is 46% which is higher compared to those of tropical root crops. A total of 218 districts are identified as highly suitable for the cultivation of elephant foot yam for different RCPs across India. A total of 209 districts are observed as highly suitable for taro cultivation across India for the two RCPs. The information about the districtlevel suitability can assist decision-makers to understand the possible shifts in the climate suitability of aroids in India in the context of food security as they have higher productivity compared to other major food grain crops.

Keywords: Elephant foot yam, taro, aroids, climate change, food security, climate suitability

Aroids are an important group of tropical root and tuber crops, which mainly constitute elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) and taro (*Colocasia esculenta* var. antiquorum (L.) Schott). Among tropical root and tuber crops, aroids are getting the least attention even though they are considered as local staple food crop in the rural tribal areas of India (Ravi *et al*., 2011, Singh *et al*., 2016). They are superior in dry matter production per hectare compared to the major food grain crops and are also rich in carbohydrate as well as mineral nutrition (Bradbury and Holloway, 1988) which make them as supplementary food to overcome malnutrition in rural tribal areas and in developing countries. Philippines, India, Malasia, Indonesia, China, and Sri Lanka are the major producers of elephant foot yam (Sunitha *et al*., 2020), and Nigeria, Cameron, China-mainland, Ghana, Papua New Guinea are the major producers of taro (FAOSTAT, 2022). They are grown over a wider range of soil and climatological conditions with a pH of 5.5 to 6.5 with a well-distributed rainfall of 1000 to 3000 mm, and 1500 to 2000 mm for elephant foot yam and taro respectively with an ideal mean temperature of 25-30°C (Sunitha *et al*., 2020; https://www.cabi.org). They have a crop period of 6 to 9 months depending on the crop variety.

Crop models are available to analyse the growth stages, yield as well as the impact of climate change and other adaptation strategies for major tropical root and tuber crops such as cassava, sweet potato, and yam (Raymundo *et al*., 2014; Moreno-Cadena *et al*., 2021). They are useful in predicting the crop growth conditions and yield in the context of changing climatic conditions. Global climate model projections indicate an increase in temperature in India in future (Singh, 2023; Balasubramanian, 2023), and this can influence the crop yield as temperature is one of the major parameters influencing the crop growth and yield among other meteorological parameters (Hatfield and Prueger, 2015). Therefore, it is important to identify climatically suitable locations for the growth of crop to avoid any yield losses due to changes in climatic conditions in India. Literature analysis indicates modeling the climate suitability of major food grain crops and tropical tuber crops are available in India (Byju *et al*., 2016; Sabitha *et al*., 2016; Shiny *et al*., 2019; Remya *et al*., 2019; Pushpalatha *et al*., 2021). Knowledge gap exists for climate/geographical suitability studies for aroidsin India. By considering the importance of aroids in the context of food security, this study focused to quantify the district-wise future climate suitability of elephant foot yam and taro in India using a species

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distribution model. The information about climate suitability of crop can assure higher crop yield without any loss due to the impact of environmental parameters. The outcome of this study can also assist decision makers to ensure food security as aroids have higher productivity compared to the major food grain crops.

MATERIALS AND METHODS

Data

The climate data for 2030, 2050, and 2070 for the two representative concentration pathways were downloaded from Coupled Model Intercomparison Project (CMIP6)-Worldclim 2.1 (Fick and Hijmans, 2017) with a resolution of 2.5 arc-minutes. The downscaled and calibrated (bias-corrected) climate data was further masked for the Indian subcontinent. QGIS platform was used to mask the climate data for the Indian sub-continent. The predicted mean values of minimum and maximum temperatures from the GCMs were used to predict the climate suitability of aroids. The crop current growth points/presence points (Fig. 1) were collected from the annual report of All India Coordinated Research Project on Tuber Crops (AICRP-TC) published in the year 2017-2018 (George and Sunitha, 2017-2018).

The MaxEnt - maximum entropy algorithm (Phillips *et al*., 2006), a species distribution machine learning approach, was used to quantify the climate suitability of aroids across India based on future climatic conditions. This study used the linear, quadratic, product, threshold, and hinge feature sets together with a value of 1 as the regularization multiplier. The input requirement of MaxEnt included raster layer of climate data and current occurrence/ presence point data of crops (Pushpalatha *et al*., 2021). The model performance was evaluated using the AUC (Area Under the receiver operating characteristic, ROC curve) value, with 0.5 showing poor performance and values greater than 0.8 showing the excellent model performance. ROC was obtained by plotting the true positive rate vs. the false positive rate for each threshold. The model was validated using the inbuilt sub-sampling option provided in the MaxEnt model (Kumar *et al*., 2014). The model output indicated the crops' lowest to highest suitability (probability of occurrence) with values ranging from 0 to 1.

RESULTS AND DISCUSSION

Current suitabilities of aroids

The MaxEnt model used to analyse the climate suitability of aroids showed excellent performance with AUC (Area under the ROC curve) values >0.8, during training and testing. This indicated its suitability to predict the future climate suitability of aroids across India. The current suitability of aroids was quantified using the baseline climate data (1960-2000) available in the worldclim. The locations which were currently suitable for the growth of these crops were concentrated in the south and north-east regions of India (Fig. 2). This information was used to understand the percentage change in the aerial distribution of these crops for future scenarios.

Future suitability

The climate suitability for near (2030 and 2050) and far future (2070) for the two representative concentration pathways 4.5 and 8.5 were analyzed. The future minimum and maximum temperature (Tmin and Tmax) distribution in India was presented in Pushpalatha *et al*. (2021) with a higher value of Tmax in the south, central, and western parts. The predicted probability by the model MaxEnt indicated lower (0) to higher (1) suitability of the aroids across India. The future climate suitability of elephant foot yam for the two RCPs was presented in Fig. 3 & 4.

The predicted climate suitability of crops by the MaxEnt model was mainly categorized into highly suitable-HS (probability is from 0.7 to 1) and moderately suitable-MS (probability is from 0.4 to 0.7) locations (Fig. 4). In a previous study, the suitability of elephant foot yam analysed by Byju *et al.,* (2016) using the EcoCrop model for AR4 scenario showed that the increase in percentage suitability varies from 0.8 to 9.6% in India by 2030. The results of this study using the MaxEnt model were also in agreement with the previous study and indicated Odisha, West Bengal, Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh, and Karnataka we highly suitable for this crop and parts of Maharashtra, Goa, Kerala, Tamil Nadu, Telangana, and Andhra Pradesh we also highly suitable for elephant foot yam in 2030 (Fig. 3). These locations remained suitable for this crop in 2050 as well. However, by 2070 (RCP-8.5) showed the crop was highly suitable in Odisha, West Bengal, Chhattisgarh, Jharkhand, Madhya Pradesh, Uttar Pradesh, Bihar, Kerala, and Andhra Pradesh. This showed the central, northeast and northern parts were highly suitable to cultivate this crop. A shifting in highly suitable locations towards north and northeast India was visible in the far future (Fig. 3).

Taro (Fig. 5 & 6) was highly suitable in the Southern peninsular and northeastern regions in the near future (2030). By 2050, the suitability of this crop shifts towards central, north, and northeastern regions of India. By 2070, Madhya Pradesh, Uttar Pradesh, Bihar, West Bengal, Jharkhand, and Kerala were highly suitable for this crop, followed by parts of Chhattisgarh, Odisha, Andhra Pradesh, Meghalaya, Goa, Maharashtra, and Karnataka. Fig. 5 clearly illustrated the states, which were highly suitable for this crop in the near and far-future scenarios. Similar to elephant foot yam, central, northeast and northern parts were also highly suitable for taro cultivation.

Fig. 7 illustrated the percentage increase in climatically suitable areas for aroids vs. tropical root crops based on the current suitability conditions for RCPs-4.5 and 8.5. The change in percentage suitability values of cassava and sweet potato were collected from Pushpalatha *et al*. (2022). The percentage suitability of area was higher for taro (49%) and elephant foot yam (46%) compared to cassava (42%) and sweet potato (32%) for future scenarios.

The overall outcome of this climate suitability analysis was presented in Table 1 & 2, which shows the total number of highly suitable (HS), and moderately suitable (MS) districts in India

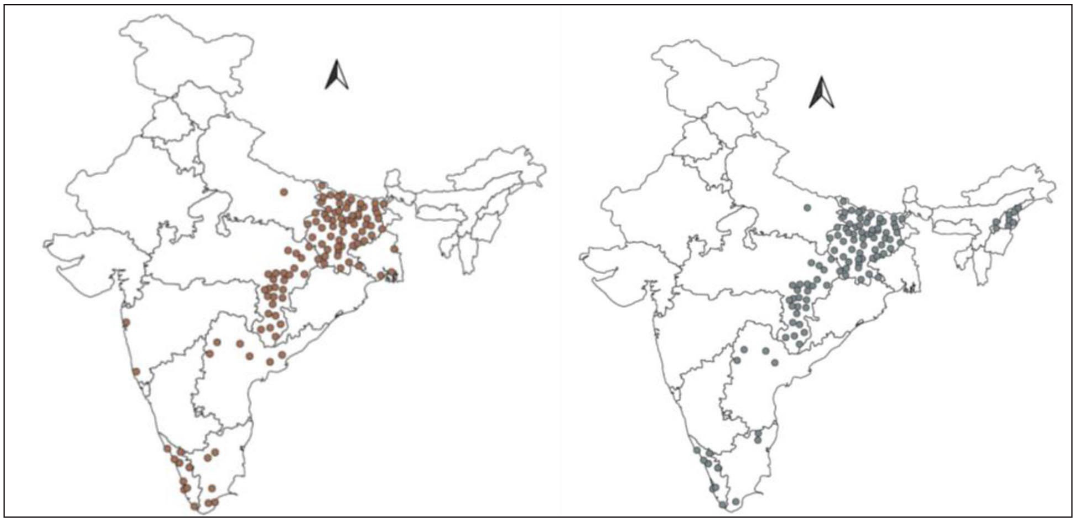

Fig. 1: Presence points of elephant foot yam and taro

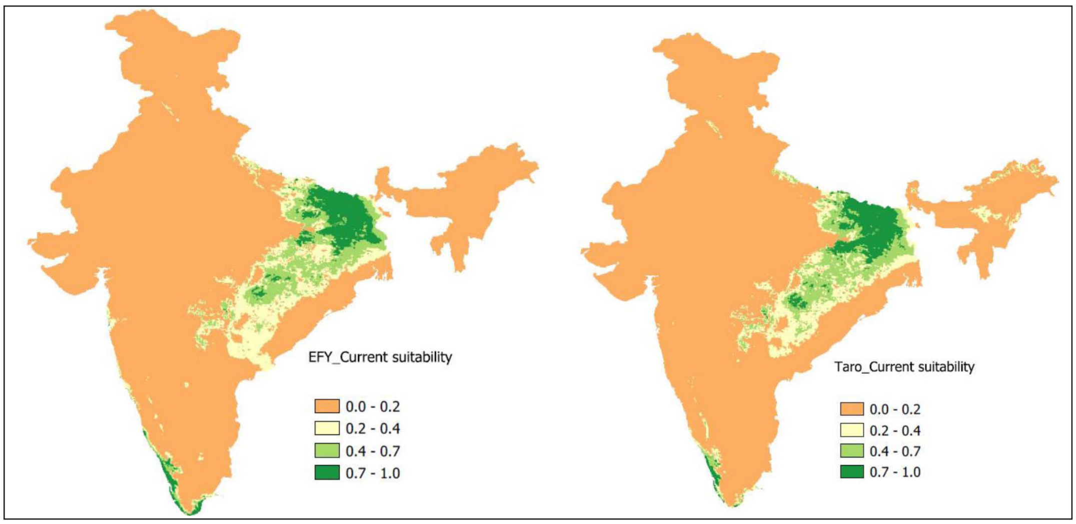

Fig. 2: The current suitability of elephant foot yam and taro

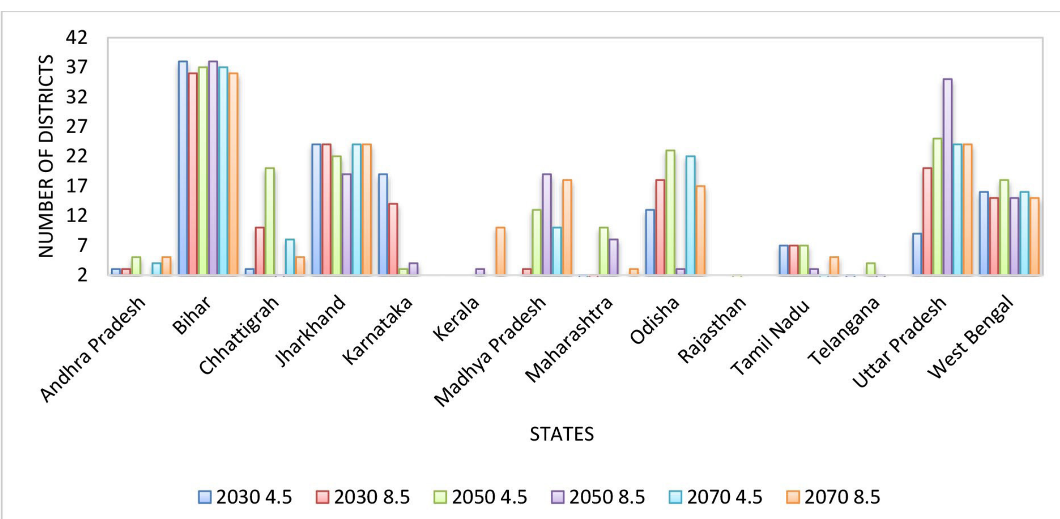

Fig. 3: States which are highly suitable for elephant foot yam in the future

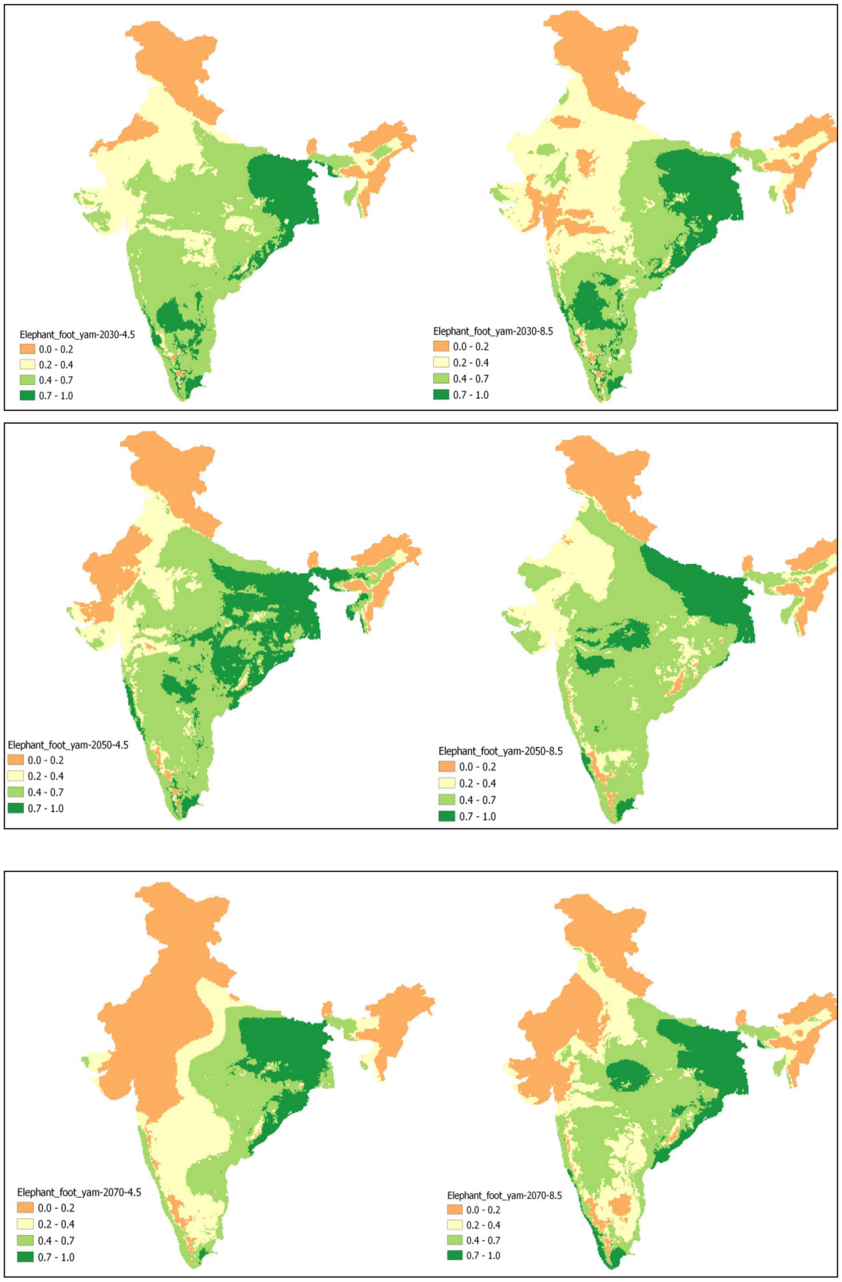

Fig. 4: Predicted climate suitability of elephant foot yam in India for 2030, 2050, and 2070for RCPs 4.5 and 8.5

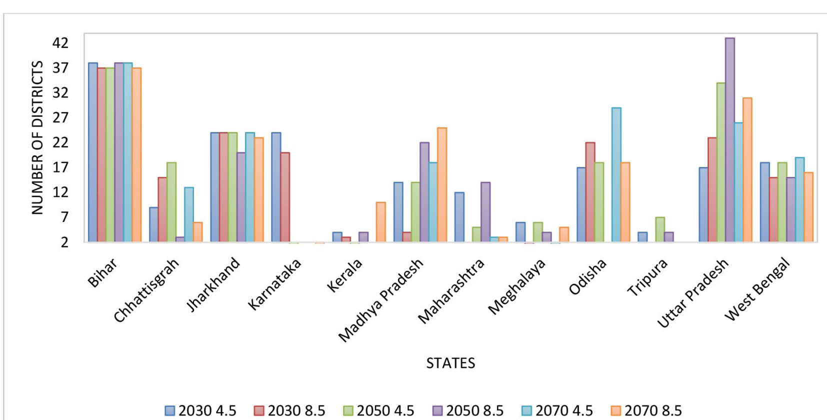

Fig. 5: States which are highly suitable for taro in the future

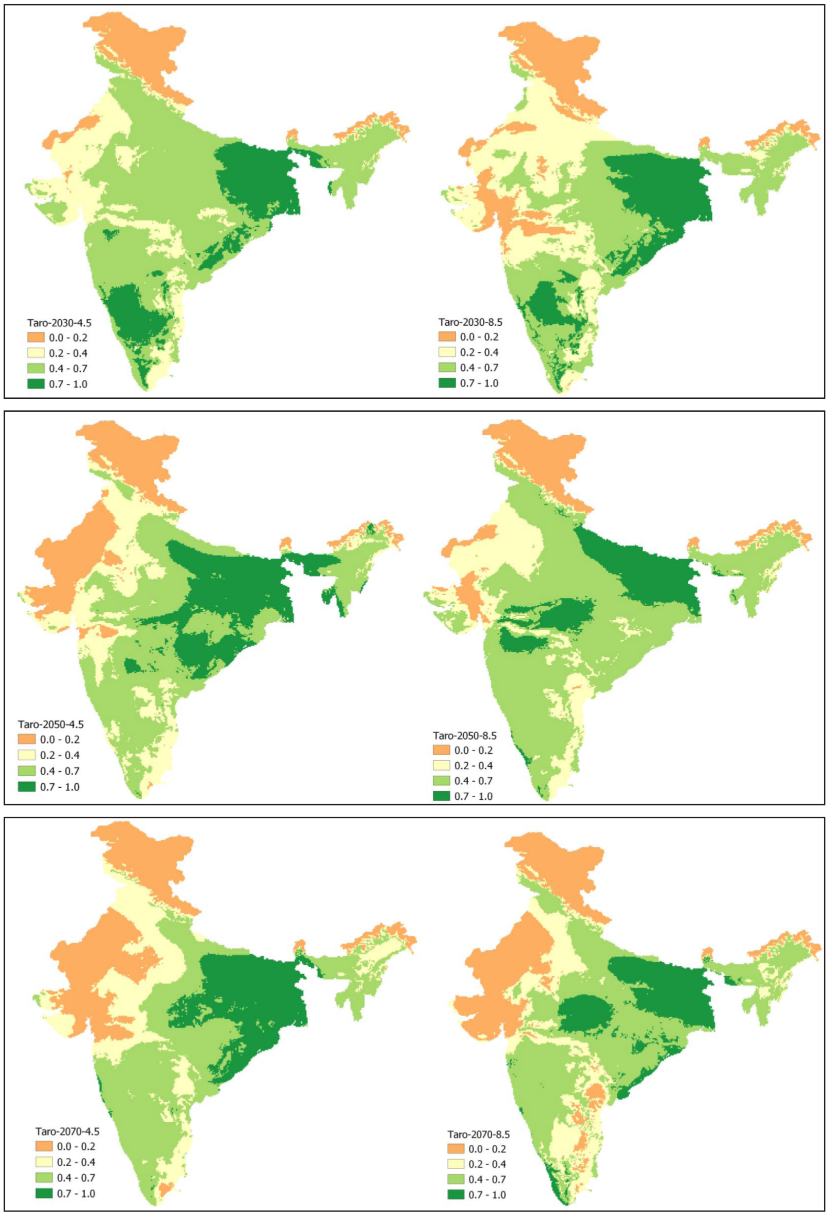

Fig. 6: Predicted geographical suitability of taro in India for 2030, 2050, and 2070 for RCPs 4.5 and 8.5

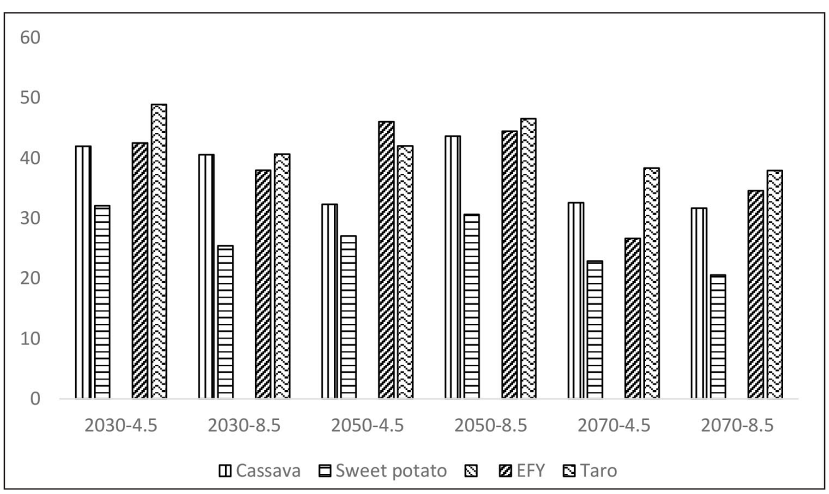

Fig. 7: Percentage increase in aerial suitability of crops in future for RCPs 4.5 and 8.5

Table 1: Number of highly suitable districts for tropical root crops and aroids in India

Crops	Current growing districts	2030		2050		2070	
		RCP-4.5	RCP-8.5	RCP-4.5	RCP-8.5	RCP-4.5	RCP-8.5
Cassava	82	194	175	170	183	139	120
Sweet potato	112	183	163	210	206	188	175
Elephant foot yam	117	139	157	218	153	147	171
Taro	113	197	172	209	179	179	188

Table 2: Number of moderately suitable districts for tropical root crops and aroids in India

Crops	2030		2050		2070	
	RCP-4.5	RCP-8.5	RCP-4.5	RCP-8.5	RCP-4.5	RCP-8.5
Cassava	237	236	206	302	253	291
Sweet potato	310	237	235	283	193	180
Elephant foot yam	317	206	262	338	139	215
Taro	383	271	278	380	260	288

for the growth of aroids along with cassava and sweet potato for the future scenarios for the RCPs 4.5 and 8.5. Number of HS and MS districts were more in case of aroids compared to cassava and sweet potato and indicated their superiority in climate suitability in the near and far future.

The study on the impact of climate change on yield for elephant foot yam and taro by Pushpalatha *et al*. (2022) were also indicated their resilience compared to rice and potato. Along with the yield variability, the outcome of climate suitability study indicated that aroids could be recommended as food security crops in the future to ensure food availability due to their higher productivity than major food grain crops.

CONCLUSIONS

This study focused to quantify the future climate suitability of major aroids-elephant foot yam, and taro. The percentage increase in climatically suitale area for taro was higher (49%) compared to elephant foot yam (46%) and other tropical root crops. The information on distrct-wise suitability and possible shift in the climate suitability of aroids towards north and northeast India could assist decision makers to develop suitable programs to ensure food availability in rural-tribal areas of India. In addition, the analysis of existing studies on these aroids showed that they could be recommended as future crops in terms of their superiority in dry matter production.

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