

LINKING GEOGRAPHIC ORIGINS OF PLANT GERMPLASM WITH CLIMATIC DATA

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Abstract

Changing climatic regimes demand identification of specific prospective genotypes to be fed to the variety development chain. Objective of the study is to designate germplasm accessions that are pre-adapted to predicted changes in climate. Information on 38,126 accessions belonging to five target crops was mined from NBPGR and relevant global databases. These accessions were geo-referenced and mapped. Climatic attributes observed over the growing season were attached to the locations and accessions were classified based on the agro-ecological zones. Comparison of temperature regimes during the crop stand between current (1950-2000) and immediate future (2010-2039) provided primary insights to select locations as well as germplasm accessions. Crop-wise subsets of genebank accessions—based on locations (source and test sites), climate matching, agronomic performance and immediate seed availability in the genebank—have been designated as pre-adapted material along with the likely locations of suitability.

About the Author



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Introduction

The National Genebank at the National Bureau of Plant Genetic Resources (NBPGR) houses the third largest *ex situ* collections in the world. On-going programmes at NBPGR focus on enhanced utilization of the genetic resources and identification of germplasm suitable for changed climatic conditions. Experts have demonstrated that the impacts of climate change can be estimated. However, no systematic efforts have been made to add value to genebank collections in terms of their climate suitability or climate readiness. Such efforts can help evaluate genebank collections by plant breeders and researchers with a focus on adaptation, thereby prepare for impact of changing climates on agricultural research as well as food and nutritional security. Pre-requisite for such an effort is to develop a national database of germplasm accessions associated with corresponding climate information (both current and future) and their mapping using GIS-based approach for the production of germplasm atlas.

We aim to link specific agronomic descriptors and geographic origins of germplasm accessions with current and future environmental data. By effectively accessing and interpreting such information, one can shortlist prospective germplasm accessions that are pre-adapted to predicted changes in climate. This is expected to improve the resilience and capacity of agricultural systems to adapt to environmental changes in India. In the absence of any previous experience, five crops were selected (i) that are important from the food security point of view in India and (ii) that have adequate number of accessions with minimum requisite passport information. In the study, five target crops selected are: wheat (*Triticum* spp.), pearl millet (*Pennisetum typhoides*), chickpea (*Cicer arietinum*), pigeon pea (*Cajanus cajan*) and sorghum (*Sorghum bicolor*). The objectives were (i) to collate data of germplasm collection sites of Indian origin in the target crops for geo-referencing and (ii) to identify selected germplasm of target crops as *climate ready collections*.

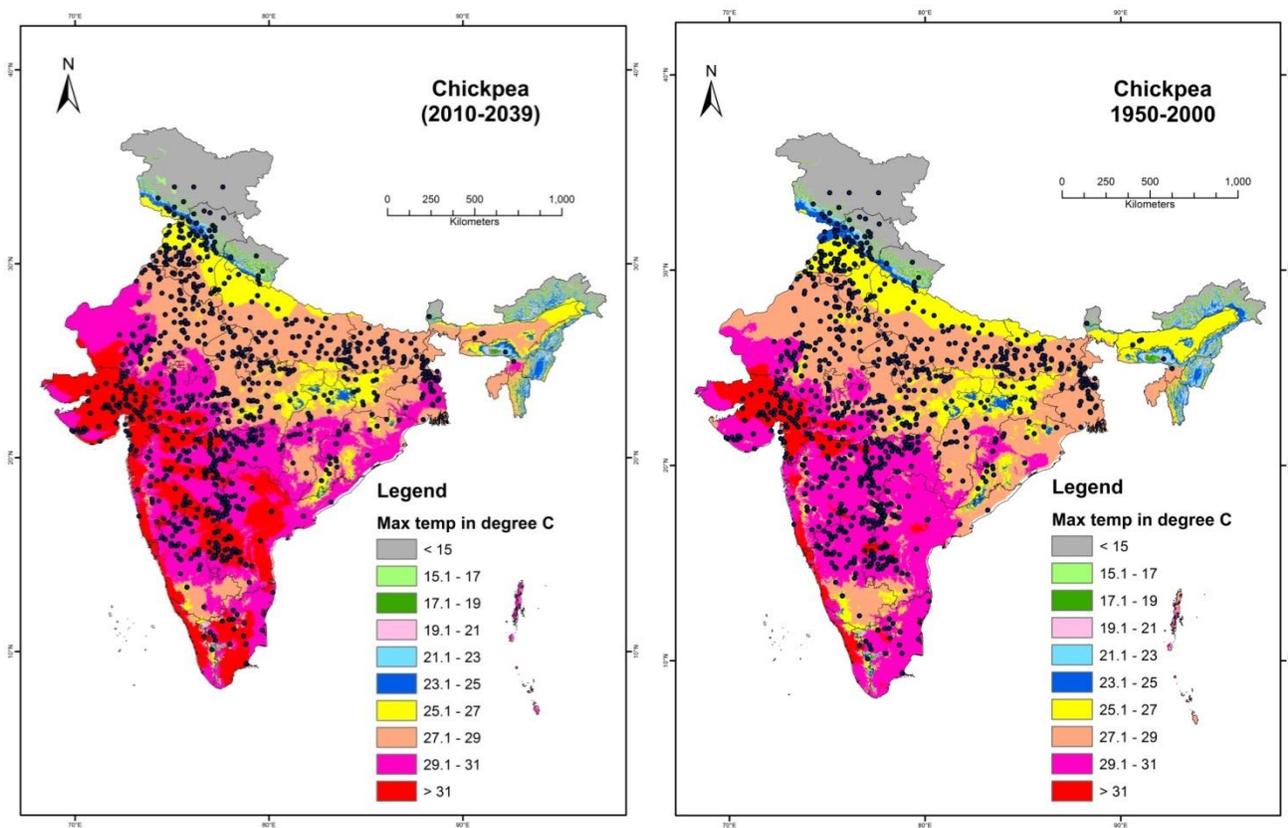
Clustering of geo-referenced germplasm accessions on the basis of climatic parameters

The best way to identify germplasm pre-adapted for changing climatic conditions is to group them based on specific traits and then select the most suitable ones. However, germplasm accessions are characterized for agro-morphological characteristics and may not have physiological attributes (root traits, canopy temperature depression, response to diurnal length, etc.) recorded. It is therefore essential to make use of passport data especially the coordinate locations of accession collection sites. In such cases, clustering of accessions requires a different approach. FloraMap is a system for producing the predicted distribution of possible adaptation for germplasm accessions based on computing the probability that a climate record belongs to a multivariate normal distribution described by the climates at the collection points of a calibration set of germplasm accessions (Jones and Gladkov, 1999). The software uses monthly rainfall totals, monthly average temperatures and monthly diurnal average range to identify sub-groups with significantly distinct climatic ranges. Since climatic parameters were used for clustering, variance was used rather than distance metrics or measures of association to cluster the points. Therefore, Ward's method was employed which involved agglomerative clustering algorithm. Each of sorghum (10947 accessions), wheat (9499 accessions), pigeon pea (6167 accessions) and chickpea (3293 accessions) were grouped into 20 clusters whereas 8220 accessions of pearl millet were grouped into 27 clusters. Clustering and mapping them onto agro-ecological zones allowed us to investigate the existence of groups of accessions with possible distinct climatic adaptations within each crop with an assumption that such groups may be associated with actual genetic differences.

Mapping geo-referenced collections on current (1950-2000) and future (2010-2039) climatic scenario

Temperature data were obtained from the Worldclim 2.5 min database for current climate (1950 – 2000) and from CSIRO -Mk3.5 General Circulation Model (GCM) SRES A1B of the CSIRO Atmospheric Research Group of Australia (2010-2039). It has been established that impacts of climate change may depend more on changes in mean minimum (T_{min}) or maximum (T_{max}) temperatures than averages. Agronomically, reduced minimum temperatures affect germination. However, Indian agriculture touted to face elevated temperatures; it is the change in maximum temperature that has attracted the greater attention. The present analysis concentrated on the changes in the *mean maximum temperatures confined to cropping season* for each of the five crop species. In order to find out areas most vulnerable to changing climate, the information was mapped employing the geospatial processing program **ArcMap**. Figure 1 illustrates, as an example, distribution of chickpea germplasm collections.

Fig: 1- Chickpea accessions mapped on climatic map based on current monthly mean max temp (left) and based on predicted monthly mean max temp (right).



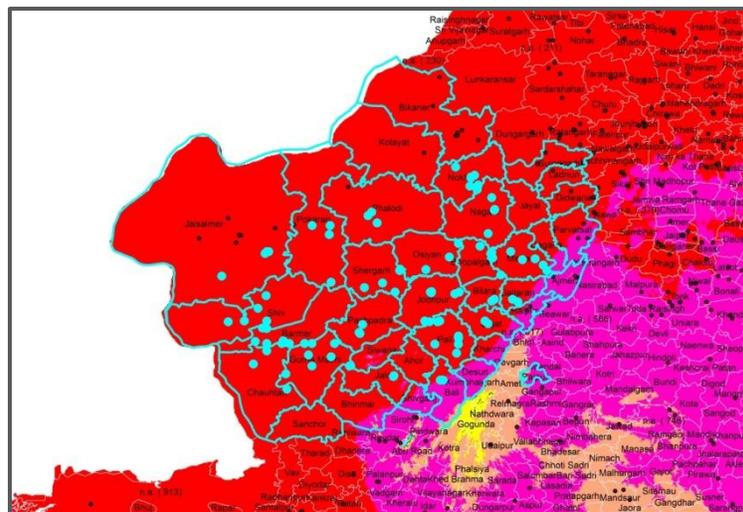
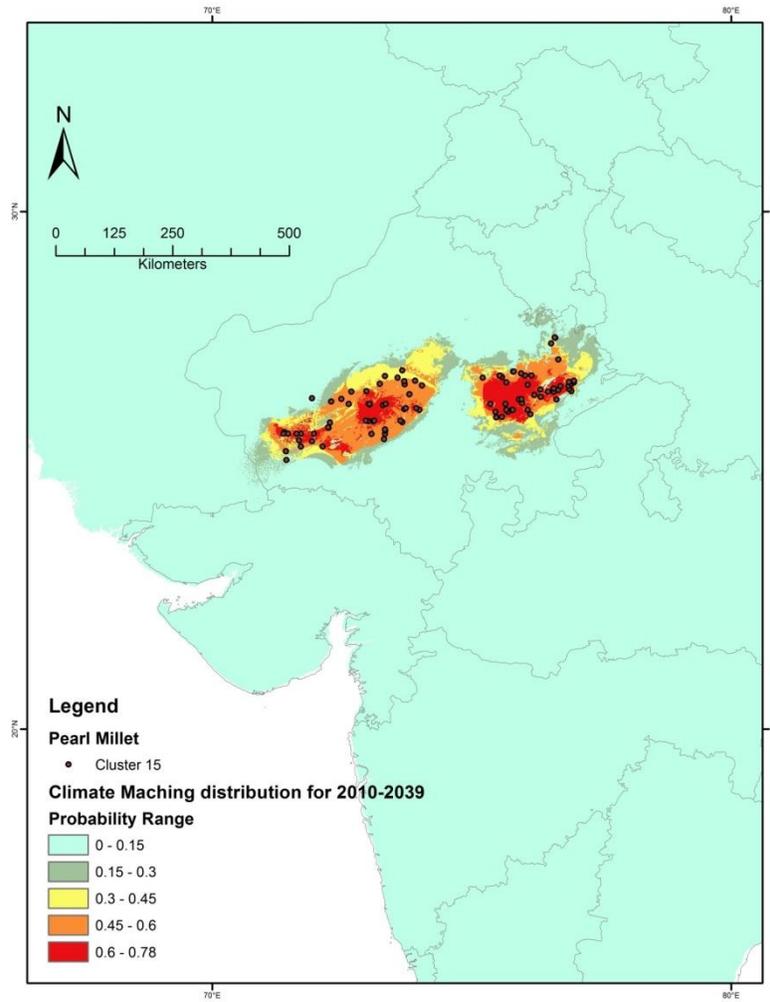


Fig: 2-Climate matching distribution for pearl millet (top figure shows one of the clusters). Bottom figure shows Location of sourcing pre-adapted material in pearl millet.

For better understanding and depiction, temperature intervals are maintained at 2 °C. It was very evident upon a quick perusal of the maps that most of the areas under cultivation are predicted to experience a shift to at least next temperature class (i.e. +2 °C mean monthly max temp). Based on close visual observation areas were identified as vulnerable with following criteria:

- a. Mean monthly max temp reaching the top bracket (at or beyond higher end of the temperature range of the crop)
- b. Fewer accessions from such putative vulnerable areas collected and conserved by NBPGR
- c. More likelihood of finding landraces, farmers varieties and other locally adapted material rather than varieties and hybrids
- d. Likelihood of subsistence farming and greater chance of genetic erosion due to climate change

We also could illustrate such areas that are most likely to go vulnerable if the predictions for 2010-2039 come true. The locations are associated with largest change in the mean monthly maximum temperatures estimated to affect plant growth and development adversely. These empirical inferences, were further supported by climate matching (present to future) carried out for each of the clusters generated by Flora Map analyses. The matching was done by employing MaxEnt program (Phillips et al. 2006). Future climate probability matching was done for these clusters using the UKMO-HadCM3 (2020s) GCM SRES A₁B of the Hadley Centre for Climate Prediction and Research/ Met Office, U.K. Figure 2 shows one such depiction in case of pearl millet. These illustrations generated using ArcMap helped (i) to identify vulnerable locations that need to be visited for exploring and collecting locally adapted diversity that in the times to come may not survive in its entirety; (ii) to show climate matching areas with greater than 0.60 probability matching were found to be shrinking; and (iii) to show best possible locations from where pre-adapted germplasm can be sourced.

Conclusions

Current study forms an empirical basis for investigating the effectiveness of climate analogue mapping tools in plant genetic resources management in terms of planning collection/recollection of germplasm accessions, and identifying sites for designating material possibly pre-adapted to impending climatic regime. However, it is important to note that analysis and interpretations come with certain limitations. For instance: prediction of the future temperature regime (lack of local temperature data, using temperature alone as an attribute, limitations of the models, etc.), identification of locations (using climate attributes alone, lack of soil data, etc.), designation of germplasm accessions as suitable to newer areas (incomplete passport data, inter-regional differences of season, soil, taste, etc.).

References

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