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NBPGR

Utilization of ex *situ* collections and climate analogues for enhancing adaptive capacity to climate change

ICAR-National Bureau of Plant Genetic Resources
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Utilization of *ex situ* collections and climate analogues for enhancing adaptive capacity to climate change

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India's first national communication to the UNFCCC and projections by the Indian Institute of Tropical Meteorology clearly show climatic changes (increased mean temperatures and reduction in precipitation) in Bundelkhand in Central India. Eighteen out of the last thirty years of recurring and long droughts, attributed to climate change, are playing havoc with the lives of 21million poor and marginalized people of Bundelkhand region. Bundelkhand has rich diversity in landraces and primitive cultivars of chickpea among other crops. It appears, all that is lost on the ground.

This report is dedicated to the farmers and people of Bundelkhand who have become unfortunate torchbearers of India's tryst with climate change.

This report is a tiny step in country's exigent and systematic responses in agriculture in general and agro-biodiversity management in particular.

Prologue

Conservation of genetic variation has been believed to be an insurance against future contingencies. Climate change is one such serious challenge confronting humanity. Agriculture cannot sustain production without adequate measures for climate adaptation. One major input to climate smart agriculture is genetic variability collected and conserved as ex situ collections in the genebanks. It is in this context that the CCAFS sponsored programme on "Utilization of ex situ collections and climate analogues for enhancing adaptive capacity to climate change" was a significant pilot study implemented by NBPGR.

This technical report describes how climate analog tools were employed to identify pre-adapted germplasm (value addition to genebank collections) and potentially vulnerable areas (for collection and conservation) in ten important crops: two each of cereals (rice and wheat), millets (sorghum and pearl millet), pulses (pigeon pea and chickpea), oilseeds (brassica and sesame) and vegetables (chilli and brinjal). The methodology comprised geo-referencing and clustering the accessions, identifying vulnerable areas, designating pre-adapted material, collecting germplasm from predicted sites, and developing database and climate maps. Long term benefits of the project include capacity building and addition of climate criteria to PGR informatics set up of NBPGR. The Project was initially sanctioned for three years at the end of which we had studied five crops. It received an extension of one year during which we could complete climate analysis in another five crops. It is important to note that the Project has not only provided funds to develop infrastructure and expertise for climate analysis of PGR but has triggered interest in using climate analysis in PGR management.

Prof. Pramod K Aggarwal, Regional Program Leader of CCAFS helped envisage the project and allocated the funds to NBPGR. He helped us to carry out the studies as a mentor and we gratefully acknowledge his support. We acknowledge the scientific and technical advice received from Dr. Prem Narain Mathur, Regional Representative of Bioversity International as a hand-holding collaborator.

Contributions of Mr. Anuj Singh and Mr. Firoz Ahmad (ICAR-NBPGR) as well as Ms. Sarika Mittra (Bioversity International, New Delhi) in data analysis and Mr. OP Dhariwal (Division of Exploration and Germplasm Collection, ICAR-NBPGR) in germplasm collection are acknowledged.

New Delhi
25th December 2015

Project Team

Contents

1 Executive summary

Climate smart agriculture demands development of new crop varieties involving the use of a wider range of intra-specific diversity so as to increase adaptability and resilience, and improve ecosystem services. As a result varietal development programmes need to be fed by genotypes with excellent adaptation potential. The best way to identify germplasm suitable for abiotic stress regimes is to evaluate them based on specific traits and then select the best ones. However, germplasm accessions —owing to their large number, nature of genetic composition and want specialized expertise and infrastructure— are normally characterized for genebank descriptors. Physiological attributes (root traits, canopy temperature depression, response to diurnal length, etc.) therefore remain unrecorded. Challenge is to prepare genebanks to be climate-ready in terms of availability of climate-ready germplasm accessions or in terms of planning and executing collection and conservation activities.

Why this study?

The study “Utilization of *ex situ* collections and climate analogues for enhancing adaptive capacity to climate change” was conceptualized and implemented to link specific geographic origins of germplasm accessions with current and future climatic data. By effectively accessing and interpreting such information, one could shortlist prospective germplasm accessions that are pre-adapted to predicted changes in climate. This was expected to improve the resilience and capacity of agricultural systems to adapt to environmental changes in India. It also meant that germplasm collection activities could be planned based on climate analysis and identification of sites immediately vulnerable to climatic changes.

The specific objectives of this pilot study were to employ climate analysis tools to identify pre-adapted germplasm (value addition to genebank collections) and vulnerable areas (for collection and conservation) in ten important crops. Germplasm data of two each of cereals (rice and wheat), millets (sorghum and pearl millet), pulses (pigeon pea and chickpea), oilseeds (brassica and sesame) and vegetables (capsicum and brinjal) were subjected to climate analysis.

Bringing together climate data and passport data: the methodology

Passport information on 64,467 accessions belonging to ten target crop species was mined from NBPGR and relevant global databases. In all, rice (17969 accessions/362 unique locations), wheat (9499 accessions/834 unique locations),sorghum (10947 accessions/1022 unique locations), pearl millet (8220 accessions/2116 unique locations), pigeon pea (6167 accessions/1005 unique locations), chickpea (3293 accessions/1138 unique locations), brassica (3597 accessions/293 unique locations),sesame CWR (348 accessions/61 unique locations), chilli pepper (4019 accessions/323 unique locations) brinjal CWR (408 accessions/142 unique locations) were georeferenced based on their collection sites and the locations were mapped.

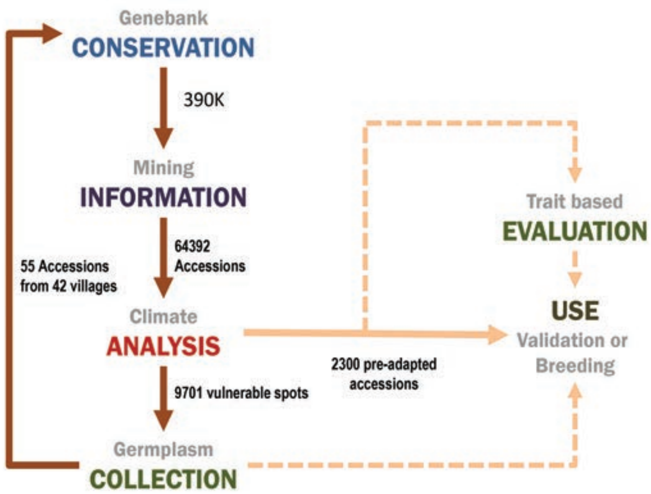


Figure 1: Overview of climate analysis of PGR

Climatic data were obtained from the Worldclim database for current climate (1950-2000) and from UKMO HADCM3 Climate Model for near future (2010-2039). Indian agriculture has been predicted to be challenged with elevated temperatures and hence upward change in maximum (*kharif*) and minimum (*rabi*) temperatures has attracted the greater attention. The present study concentrated on the changes in the mean maximum temperatures during the cropping season for each of the ten crop species. In order to find out areas most vulnerable to changing climate, the information was mapped employing the geospatial processing program ArcMap.

Climate analysis can identify germplasm pre-a dapted to elevated temperature and guide collection activities

Climate maps, depicting the possible locations of germplasm occurrence on current and future temperature maps, were generated for all the ten crops. Sites with current climate variables, that make crops vulnerable in the future, were identified for each crop. Genebank accessions originating from these sites were designated as pre-adapted material.

Based on locations (source and test sites), climate matching, available agronomic performance data and seed availability in the genebank, 12 wheat accessions, 875 rice accessions, 150 sorghumaccessions, 822 pearl millet accessions, 82 chickpea accessions, 43 pigeon pea accessions, 99 accessions of sesame wild relatives,198 chilli-pepper accessions and 12 accessions of brinjal wild relatives have been designated as pre-adapted.

Locations that are predicted to become vulnerable to elevated temperatures were listed for each crop. Each site is delimited by smallest administrative boundary called taluk for ease of planning exploration and collection missions. As many as 2039 Taluks for wheat, 912 for rice, 593 for pearl millet, 541 for sorghum (*kharif*), 1174 for sorghum (*rabi*), 1445 for chickpea, 728 for pigeon pea 178 for oil seed brassica, 912 for sesame CWR 616 for chilli-pepper and 563 for brinjal CWR were predicted as vulnerable and to draw immediate attention to conduct collection missions.

Notwithstanding the imperfections in the data, procedure and models, the study could identify specific germplasm accessions and locations. Subsequently, missions were planned to collect germplasm from (i) sites that were predicted to go vulnerable in near future in the changing climatic regime and (ii) sites where germplasm adapted to higher temperature were predicted to occur. Exploration missions were executed as per the procedures established in NBPGR for four crops (wheat, chickpea, pearl millet and sorghum) and 56 germplasm accessions from 42 villages were collected. Following standard genebank procedures, the accessions were conserved in the National Genebank.

Before validating the adaptive capacity of the accessions for elevated temperature regimes and their suitability to other areas, it was ascertained using molecular markers that genetic differences among different samples collected from a village cluster actually existed.

PGR-CLIM, an interactive online application was developed to view climate maps generated in the study.

Capacity building

We organized a 5-day "Regional Training Workshop on GIS and Climate Analogue Tools for PGR Management and Enhanced Use" during 2-6, December 2013 at NBPGR, New Delhi. The aim of the Workshop was to impart contemporary knowledge on GIS, climate data, climate analogues and their applications in PGR management and utilization along with hands-on experience on various software, databases, clustering and analyses.Participants had an opportunity to listen to presentations by experts on select topics (25% of the time) and work hands-on (75% of the time).The participants included eight persons from ICAR institutes, one each from SAU and CSIR, and four from neighboring countries of the South East Asia (Vietnam, Laos and Cambodia) engaged in PGR management and interested in employing climate analogue tools. Indian participants were supported by dedicated funds available in the project whereas foreign participants were fully sponsored by our collaborator in the project, Bioversity International.

Conclusions and future prospects

The project introduced the power and potential of climate analog tools for value addition to the conserved germplasm as well as identification of vulnerable sites. Based on analyses, accessions of all ten selected crop species have been listed as climate ready. These need further evaluation for their suitability to the new sites. Tools for predictions and identification of vulnerable sites are becoming more sophisticated and realistic. These tools need to be employed for identification of critical sites for collection and recollections. An analysis of what to collect in terms of CWR and populations, extent of variation in terms of genetic variability, and contribution to adaptive capacity in terms of novel genes and alleles need to be carried out. Such studies will be able to evaluate the process of prediction based on climate models.

2

Introduction

Effect of climate change on agriculture and ways to mitigate and adapt have been well documented[1]. Adaptation strategies demand maintenance of genetic diversity[2], identifying and cultivating crops and cultivars that have maximum phenotypic plasticity[3], and diversified rotations of crops and crop varieties with disparate heat endurance and marginal yield variability[4]. Successful adaptation of agricultural production systems to climate change calls for deployment of genetic diversity[5] to breed climate-adapted crop varieties[6,7]. Genebanks, the custodians of plant genetic resources (PGR), worldwide are therefore mandated to identify and collect diverse cultigens (landraces, varieties, and feral forms) and crop wild relatives (CWRs) from target ecologies, and conserve them to meet the demands.

On the other hand, PGR are severely affected by climate change in terms of their occurrence, distribution and diversity. While research on the effects of climate change

[1]Vermeulen et al (2012). Options for support to agriculture and food security under climate change. Environmental Science & Policy, 15(1), 136-144.

[2]IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. A Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change World Meteorological Organization, Geneva, Switzerland, 190 pp.

[3]Mercer and Perales(2010).Evolutionary response of landraces to climate change in centers of crop diversity.Evolutionary applications, 3(56), 480-493.

[4]Lipper at al (2010). Climate-smart agriculture: policies, practices and financing for food security, adaptation and mitigation. Rome: Food and Agriculture Organization of the United Nations.

[5]López-Noriega et al (2012).Flows under stress: availability of plant genetic resources in times of climate and policy change.Working paper no.18. Copenhagen, Denmark. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

[6]Beddington et al (2012). What next for agriculture after Durban? Science 335: 289–290.

[7]FAO (2015).Coping with climate change – the roles of genetic resources for food and agriculture. Rome.

on PGR including CWR continues to be limited[8], observations on the naturally occurring plant species especially in the mountainous regions have shown that climate change could bring about changes in the phenology, shifts in species' distributions, and even substantial range contractions and species extinctions. CWRs and locally adapted landraces occur in the natural habitats and farmlands most optimal for their growth and reproduction. For over centuries, as environmental conditions have changed, cultigens (landraces, varieties, and feral forms) have adapted and flourished. However, the speed and complexity of human-induced climate change are likely to present unprecedented challenges[8], and changes in the temperature and moisture availability regimes can seriously affect their predominance in the native ecologies. The plant diversity niches are known to become vulnerable due to genetic erosion. Many centres of landrace diversity lie in vulnerable regions and because of changing climate, landraces are likely to be lost[8].

Crop-biodiversity management, therefore, has to be prioritized on a twin-track approach for genebanks to be climate ready

(i) First, to consolidate genebank collections of cultigens and CWR from vulnerable areas especially of those species that are narrowly adapted and endemic in occurrence and to conserve them *ex situ*.

(ii) Second, to feed varietal development programmes with trait-specific intra-specific diversity so as to increase adaptability and resilience, and improve ecosystem services.

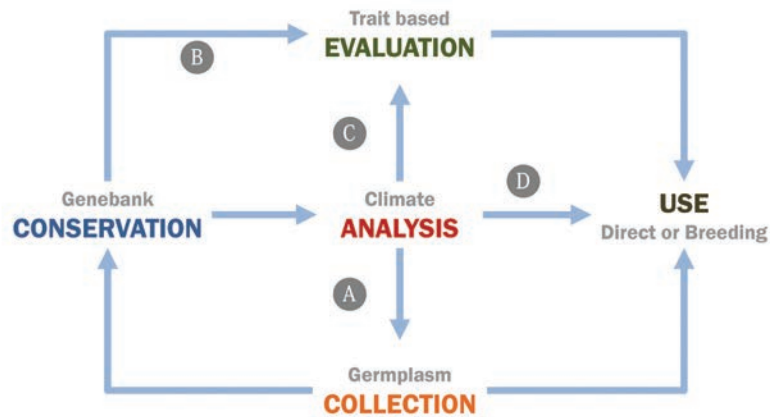


Figure 2: Role of climate analysis in germplasm collection, conservation and use.

[8]Joshi et al (2008). Ex situ and in situ management of wild and weedy rice in Nepal using a geographical information system. Plant Genetic Resources Newsletter 155:69-74.

Genebanks can make informed decisions about identifying vulnerable areas and planning germplasm collecting (Fig 2A). For instance, collections in rice and wheat were made in Nepal from such locations identified based on geographic information system tools[8].

Identification of genotypes with excellent adaptation potential, to be supplied to breeders, is traditionally achieved by detailed evaluation of germplasm for specific physiological attributes (root traits, canopy temperature depression, response to diurnal length, etc.), and then select the best performing accessions (Fig 2B). Screening even a part of seven million accessions held worldwide in genebanks is a herculean task. Alternatively, it is possible to make use of passport data especially the coordinate locations of germplasm collection sites to estimate adaptive capacity of each accession (Fig 2C). An immediate priority for genebanks could be to introduce genotypes from historically warmer climates with higher average relative fitness (pre-adapted germplasm) than local genotypes and therefore have potential to outperform natives in changed climates[9]. Identification of pre-adapted material and their introduction (Fig 2D), therefore, offer a compelling practical possibility. Identification of the pre-adapted germplasm that are already conserved, therefore, becomes a priority activity for the genebanks around the globe.

The genebank at the National Bureau of Plant Genetic Resources (NBPGR) is one of the largest in the world in terms of *ex situ* collections. 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 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. An FAO study[10] has called for increased need for consolidating collections of wild species, including crop wild relatives, due to increased likelihood of extinction for narrowly adapted and endemic species. The study has also predicted novel and increased demands on germplasm in genebanks for adapting

[9]Wilczek(2014). Lagging adaptation to warming climate in Arabidopsis thaliana. Proceedings of the National Academy of Sciences, 111(22), 7906-7913.

[10]Jarvis et al. 2010.Climate Change and its Effect on Conservation and Use of Plant Genetic Resources for Food and Agriculture and Associated Biodiversity for Food Security. FAO, Rome.

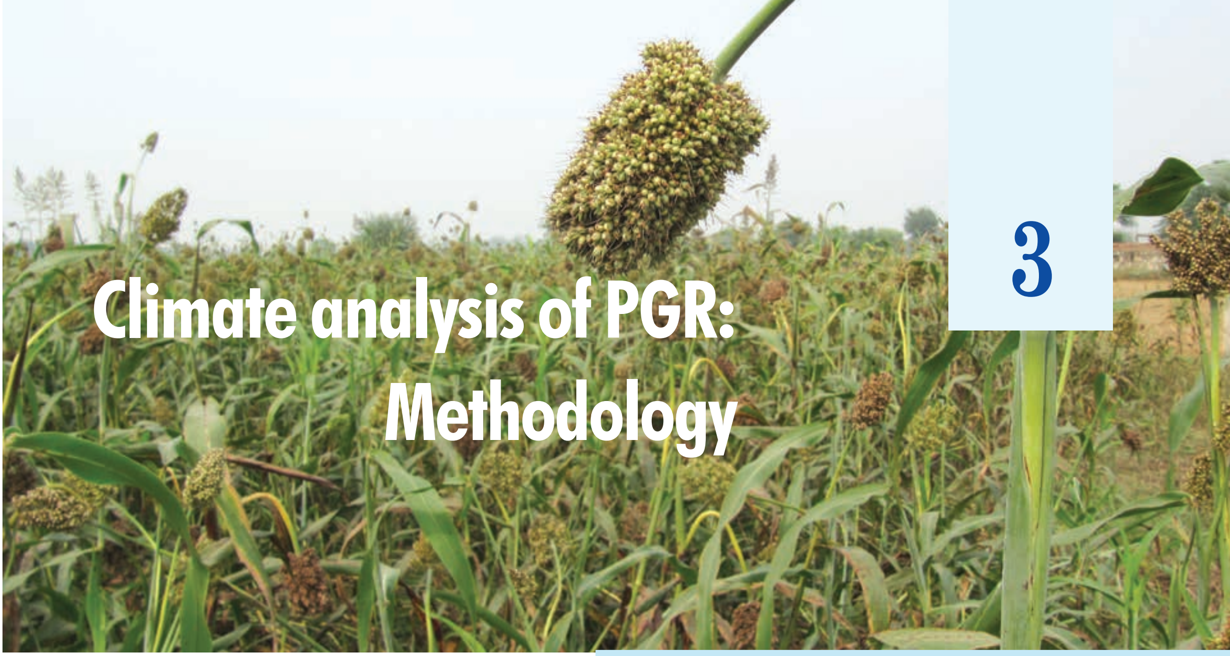
agricultural practices to climate change, including the need to screening for different characters.

It is in this context that the project "Utilization of *ex situ* collections and climate analogues for enhancing adaptive capacity to climate change" was conceptualized and implemented 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 could shortlist prospective germplasm accessions that are pre-adapted to predicted changes in climate. This was expected to improve the resilience and capacity of agricultural systems to adapt to environmental changes in India.

For NBPGR, this was a beginning and in the absence of any previous experience of climate analysis of genebank collections, study was planned in ten important crops. Germplasm data of two each of cereals (rice and wheat), millets (sorghum and pearl millet), pulses (pigeon pea and chickpea), oilseeds (brassica and sesame) and vegetables (capsicum and brinjal) were subjected to climate analysis[11]. The crops selected (i) were important from the food security point of view in India and (ii) had adequate number of accessions in the genebank.

This report illustrates the results of efforts to link geographic origins of germplasm accessions collected from India with current and future environmental data. The specific objectives of the study, carried out in the Indian context, were to employ climate data to identify vulnerable areas (for collection and conservation) and pre-adapted germplasm (for immediate direct use or in varietal development) in the ten select crops. The outcome of the work is expected to prioritize crop-biodiversity collection and conservation in Indian genebank for enhancing adaptive capacity to climate change.

[11]At the time of project formulation five target crops were selected: wheat, pearl millet, chickpea, sesame and cluster bean. Subsequent to interim review of the project in the first year, sesame and cluster bean, for want of data availability, were replaced by pigeon pea and sorghum. As a result of excellent progress achieved, at the end of third year, one year extension was granted. Due to the experience gained and expertise developed, data on five additional crops (rice, brassica, chillies, and CWR of sesame and brinjal) were analysed.



3

Climate analysis of PGR: Methodology

Data mining and geo-referencing

The generic methodology included building databases of (i) geographical locations from where germplasm accessions were collected (as best guess for occurrence of germplasm) and seasonal temperature distribution (simple representation of current and future climates). By overlaying germplasm sites onto climate change, it would be possible to predict and analyse effects on PGR *in situ*/on-farm. To address specific questions, our methodologies involved variations, although generic procedure was the same. For instance, passport data of wheat, sorghum, pearl millet, pigeon pea and chickpea were mined from all the sources whereas data on others were extracted only from NBPGR databases. Statistical clustering and climate matching in wheat, sorghum, pearl millet, pigeon pea and chickpea were carried out before pinpointing locations. On the other hand, direct image based deduction method was followed in rest of the crops to identify locations.

Passport data of germplasm accessions of the target crops conserved at National Genebank, NBPGR, New Delhi, were accessed through NBPGR databases. To obtain information on international collections of the target crops sourced from India and being conserved at locations other than National Genebank, NBPGR, passport data were obtained from documentations of Bioversity International collection missions (IBPGR database) or accessed via either ICRISAT database or GENESYS portal.

Subsequent to the verification of the botanical identity, information on geographical location was screened for availability and correctness of details on latitude and longitude of the collection sites. In the absence of village information for a substantial number of accessions, district HQ was used as minimum collection site information for mapping. The data sets thus obtained were combined and arranged with common data standards; duplicates were identified and removed; rigorously screened for information on geographical location (latitude and longitude) of the collection sites. Accuracy and completeness, of the passport data especially for the location of collection, were highly critical for precise climate based predictions. Passport data of indigenous collections available in the databases were screened meticulously. Out of 2,21,905 rice accessions only 21,654 were considered for the study. Similarly, data of 3,597 of 24,401 brassica accessions, 4,019 of 17,535 chilli accessions, 348 of 4,428 sesame CWR accessions, 408 of 30,097 brinjal CWR accessions 10,947 of 47,171 sorghum accessions, 9,499 of 1,21,564 wheat accessions, 8,220 of 21,360 pearl millet accessions, 6,167 of 16,914 pigeon pea accessions and 3,597 of 31,405 chickpea acessions were included in the study.

In Wheat, rice, sorghum, pearl millet, pigeon pea, chickpea, brassica and chilli pepper, study was based on information on cultivated species; in sesame and brinjal, study was based on information on crop wild relatives (CWR). CWRs occur in nature at specific niche ecologies where they have adapted. Climate change in terms of temperature rise can affect the developmental stages in wild species and can throw them out of sync with seasons. This can lead to loss of allelic and species diversity. In the present study, analysis was focused on crop wild relatives of brinjal and sesame, two of the crop species of Indian origin with many wild species occurring in the country. For instance, in case of brinjal, information on as many as 408 germplasm accessions belonging to following 20 species was used: *Solanum incanum, Solanum indicum, Solanum esculentum, Solanum xanthocarpum, Solanum nigrum, Solanum aethiopicum, Solanum torvum, Solanum trilobatum, Solanum macrocarpum, Solanum viarum, Solanum incanum, Solanum gilo, Solanum spirale, Solanum insanum, Solanum capsicoides, Solanum sisymbrifolium, Solanum violaceum, Solanum virginianum, Solanum americanum*and *Solanum villosum*. Similarly, in case of sesame, information on as many as 348 germplasm accessions belonging to following eight species was used: *Sesamum mulayanum, Sesamum radiatum, Sesamum malabaricum, Sesamum prostratum, Sesamum alatum, Sesamum orientale, Sesamum anamalayansis, Sesamum laciniatum*.

Accessions with spatial information were manually geocoded and were brought into GIS to prepare a geo-database. The locations from where these accessions were collected were then mapped on the broad agro-ecological zones (AEZ)[1,2].

[1]FAO (2005). Fertilizer use by crop in India. First version, published by FAO, Rome.

[2]Sehgal et al (1992). Agro-Ecological Regions of India. 2nd Edition, Tech. Bull. No. 24, NBSS and LUP. 130p.

Climate data

Due to the constraints of unavailability of accurate and adequate data in terms of temporal rainfall distribution and to study one factor at a time, only temperature variable was taken into account for analysis, assuming other factors constant. Seasonal mean maximum temperatures were identified as the climate variable for the study. Climatic data were obtained from the Worldclim database for current climate (1950-2000) and from UKMO HADCM3 Climate Model for near future (2010-2039). In order to find out areas most vulnerable to changing climate, the collection sites as putative sites for occurrence of diversity were mapped on current and future climate. The information at every stage of analysis was mapped employing the geospatial processing program ArcMap 10.1 (ESRI 2010).

Clustering and climate matching

In the first study utility of clustering the collection sites was analyzed in five crop species (wheat, sorghum, chickpea, pigeon pea and pearl millet). Accessions of each of the these target crops had been collected from several locations across AEZs. Sites of germplasm collections in each crop that share similar climatic conditions were identified statistically. The likelihood that each of these sites belongs to a multivariate normal distribution determined by the climatic variables was computed. Ward's variance estimates of climatic attributes (monthly rainfall totals, monthly average temperatures and monthly diurnal average range) of locations were used to agglomeratively cluster the points employing FloraMap[3]. Climate matching (present to future) was carried out for each of the clusters generated by FloraMap analyses[4] by subjecting the clusters to maximum entropy method for modelling geographic distributions of collections sites. The matching was done by employing MaxEnt program[5].

[3]Jones and Gladkov (1999). FloraMap: A computer tool for predicting the distribution of plants and other organisms in the wild. CIAT, Colombia.

[4]Jones et al (2002). Computer tools for spatial analysis of plant genetic resources data: 2. FloraMap. Plant Genetic Resources Newsletter, 130, 1–6.

[5]Phillips et al (2006). Maximum entropy modeling of species geographic distributions. Ecol Model 190:231–259.

Vulnerable and pre-adapted sites were identified based on following considerations:

- Mean monthly max temperature reaching the top bracket (at or beyond higher end of the temperature range of the crop)
- Accessions from such areas collected and conserved by NBPGR
- More likelihood of finding landraces, farmers varieties and other locally adapted material rather than improved varieties and hybrids
- Likelihood of subsistence farming and serious chance of genetic erosion due to climate change

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, designation of germplasm accessions as suitable to newer areas (incomplete passport data, inter-regional differences of season, soil, taste, etc.).

Exploration and germplasm collection

Exploration and collection missions were planned based on predictions of future climate. Standard germplasm collection procedures (NBPGR 2009) were followed to sample landraces either from farmer's field by random method or by bulk method from the storage bins in the households. Post-collection procedures of seed processing, accessioning and deposition in the genebank were as per established standards (NBPGR 2009).

Genetic diversity analysis

Diversity among landraces results from natural and farmer-mediated evolutionary forces. Crop landraces respond to climatic changes through phenotypic plasticity, gene flow and evolution. In addition to adaptive traits, understanding patterns of neutral diversity in populations may help understand how landraces will continue to evolve and how to minimize genetic erosion[6]. Simple sequence repeats (SSR) markers, considered gold standard in molecular marker analysis, were employed as per standard methodology[7] to investigate the genetic diversity pattern among the germplasm accessions of sorghum, pearl millet, chickpea and wheat.

[6]Mercer and Perales (2010). Evolutionary response of landraces to climate change in centers of crop diversity. Evolutionary applications, 3(56): 480-493.

[7]Archak et al (2003). Comparative assessment of DNA fingerprinting techniques (RAPD, ISSR and AFLP) for genetic analysis of cashew (*Anacardiumoccidentale* L.) accessions of India. Genome, 2003, 46(3): 362-369.

4

Results: Climate maps

Data mining and georeferencing of germplasm collection sites

Passport information on 64,467 accessions belonging to ten target crop species was mined from NBPGR and relevant global databases. In all, rice (17969 accessions/362 unique locations), wheat (9499 accessions/834 unique locations),sorghum (10947 accessions/ 1022 unique locations), pearl millet (8220 accessions/2116 unique locations), pigeon pea (6167 accessions/1005 unique locations), chickpea (3293 accessions/1138 unique locations), brassica (3597 accessions/293 unique locations),sesame CWR (348 accessions/ 61 unique locations), chilli pepper (4019 accessions/323 unique locations) brinjal CWR (408 accessions/142 unique locations) were georeferenced based on their collection sites and the locations were mapped.

Table 1. Details of crops and germplasm accessions

Crop	Accessions geo-referenced[1]	Unique locations[2]	Crop	Accessions geo-referenced[1]	Unique locations[2]
Rice	21654	362	Chickpea	3293	1138
Wheat	9499	834	Brassica	3510	293
Sorghum	10947	1022	Sesame CWR	348	61
Pearl millet	8220	2116	Chilli pepper	4019	323
Pigeon pea	6167	1005	Brinjal CWR	408	142

[1]Accessions collected from India and whose location information was available

[2]Site of primary collection (at least district documented while collecting)

When collections were mapped on agro-ecological zones, it was observed that the collection sites primarily belonged to semi-arid to sub-humid regions with hot semi-arid topping the list (**Figure 3**).

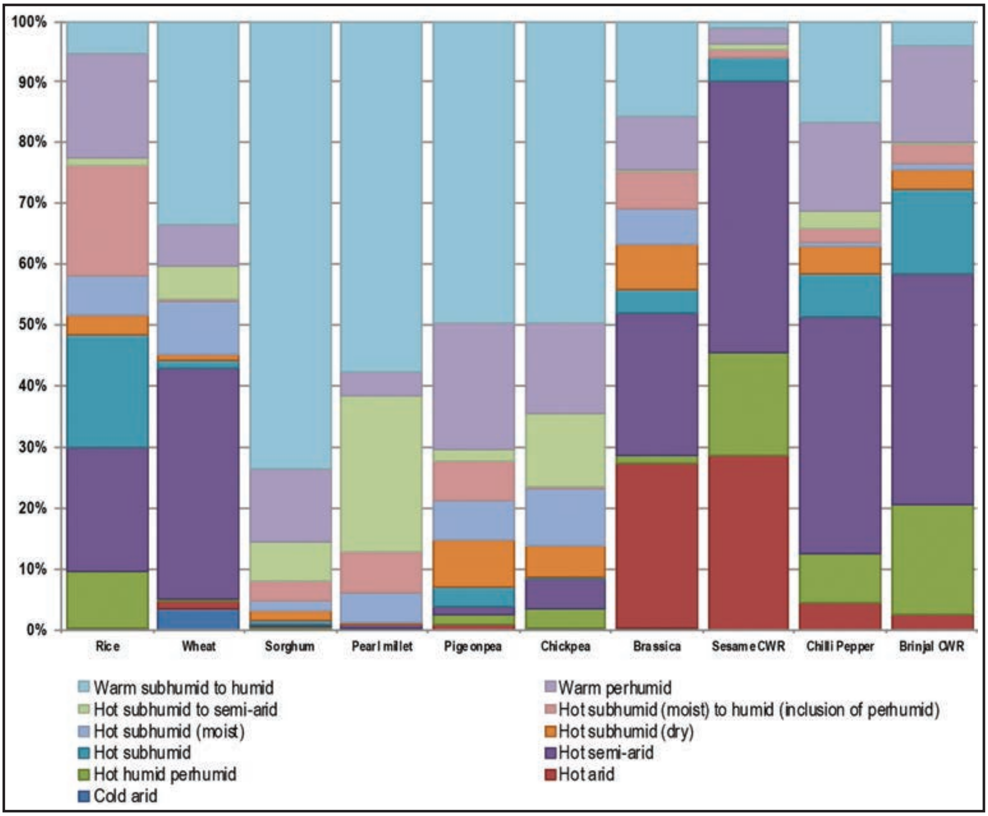


Figure 3. Distribution of germplasm collection sites (proxy for locations of germplasm occurrence) across agro-ecological zones[1] of India

Grouping collections sites based on elevation and clustering them

Effect of elevation of the locations of germplasm occurrence was investigated in five crop species. In order to short list collection sites for vulnerability or adaptability, geo-references were classified based on the agro-ecological zones (**Figure 4**) and the collections sites were categorized into altitude groups using elevation data of the sites based on CGIAR-SRTM data sourced through DIVA-GIS.

[1]FAO (2005).Fertilizer use by crop in India.First version, published by FAO, Rome.

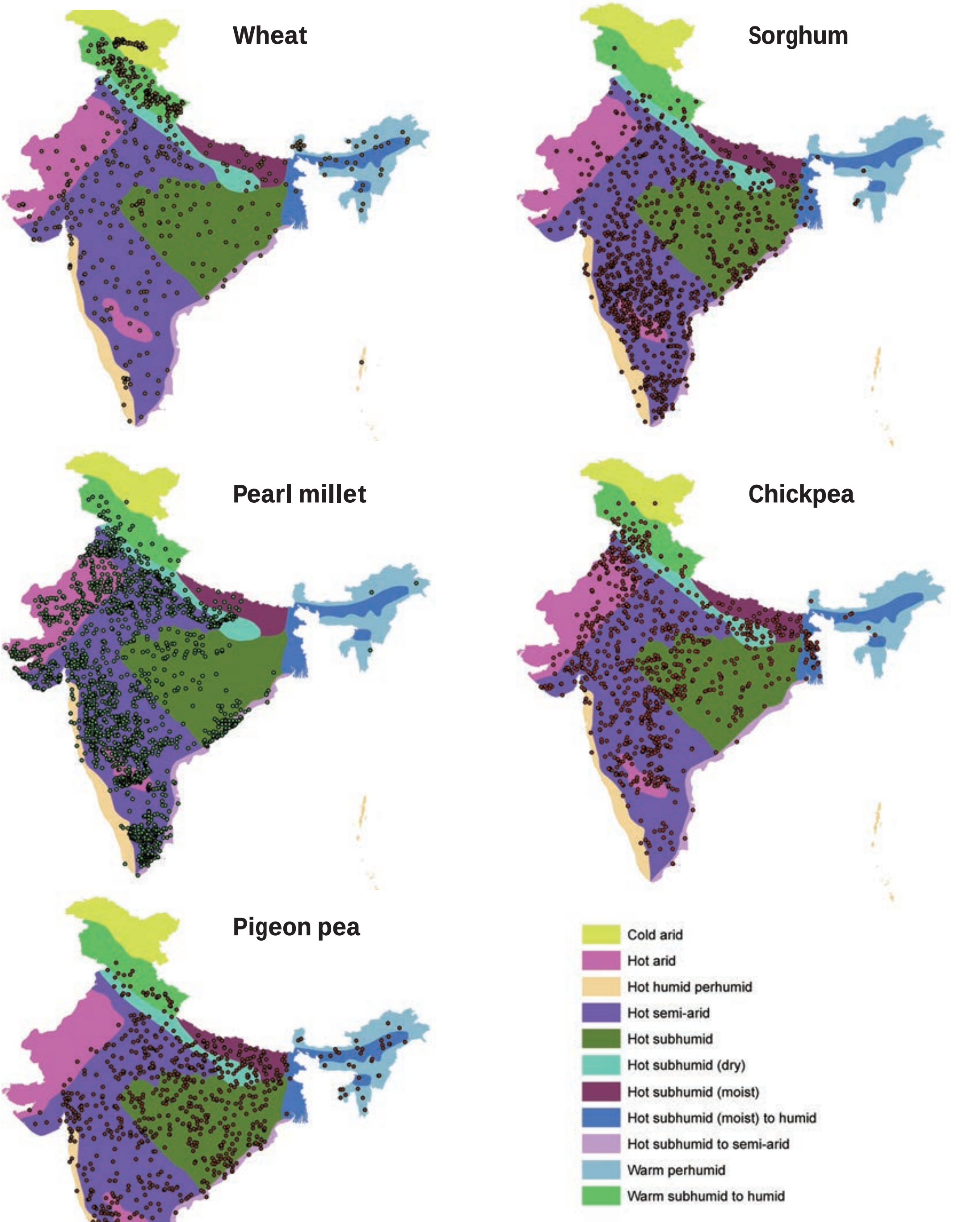


Figure 4. Mapping and clustering of germplasm collection sites.

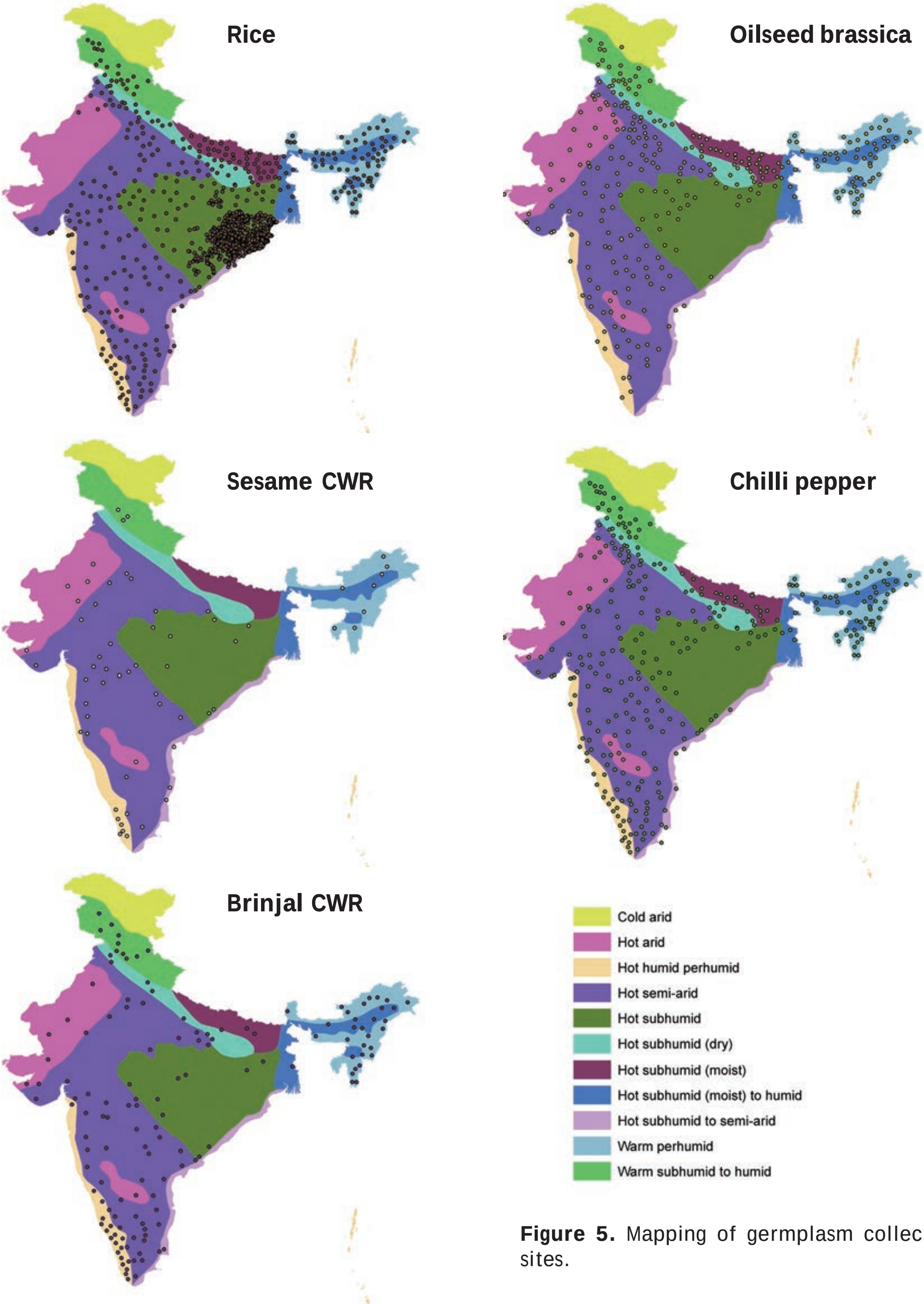


Figure 5. Mapping of germplasm collection sites.

Out of 21,654 rice germplasm accessions, 21% were collected from hot semi-arid regions, 19% from hot sub-humid regions, 18% from hot sub humid to humid region and 17% from warm per-humid region. Presence of rice germplasm throughout India was evident from the distribution. Although germplasm was collected from hot sub-humid and hot sub-humid to semi-arid regions, their suitability to other areas that may experience hotter and drier spells in future cannot be taken for granted. Grain characteristics and cuisine for farmer acceptance and soil nutrient status for adaptation may become crucial.

Out of 9,499 wheat accessions geo-referenced (80% bread wheat and the rest durum or macaroni wheat), nearly equal (34% and 38%) locations of collections belonged to hot semi-arid and warm sub-humid to humid regions respectively. Distribution of mean maximum temperatures at sites up to 1000m elevation was nearly identical. However, in the sites up to 500m a spike in the temperature at the terminal stages of the wheat crop appeared pronounced and collections from these sites were more likely to be pre-adapted to terminal heat.

Out of 8,220 germplasm accessions of pearl millet, more than half (~58%) of the collection sites belonged to hot semi-arid regions and about 26% were collected from hot arid regions. Irrespective of the elevation of the location, entire pearl millet cultivation is completed within a 2 °C window of mean maximum temperatures. Collections from sites with elevations from 201m to 400m appeared to experience exposure to maximum temperature and minimum rainfall. Pearl millet collections from this group are more likely to be pre-adapted to drought conditions. Pearl millet collections from altitudes beyond 800m are less likely to be useful for this trait as these locations receive maximum rainfall in addition to being around 25 °C throughout the cropping period.

Out of 10,947 sorghum accessions (both kharif and rabi), nearly 74% were collected from hot semi-arid regions and another 12% from hot sub-humid regions. Both kharif (June to Oct) and rabi (Oct to Feb) crops are important crops in India. Sorghum collections from sites with 201-400m altitude withstand >37 °C. Sorghum and pigeon pea being hardy crops, identifying best pre-adapted material depends upon the identification of crucial crop period, elevation of the target areas and temperature-precipitation pattern in the future.

Out of 3293 germplasm accessions of chickpea, half were collected from hot semi-arid regions and 15% and 12% were collected from hot sub-humid and hot arid regions respectively. Distribution of mean maximum temperatures over sites up to 600m elevation was similar in the first half of the crop duration. However, a spike in the temperature in the last 30 days of the crop was pronounced in the locations with altitude 401-600m. A closer look at the collections from these locations could to throw up pre-adapted genotypes.

Out of 6,167 germplasm accessions of pigeon pea, 50% were collected from hot semi-arid regions and 21% of them originated from hot sub-humid regions. Pigeon pea collections (from sites up to 600m elevation) experience temperatures upwards of 30 °C during most of the crop stand and least average rainfall.

Out of 3510 germplasm accessions of oilseed brassica, 27% were collected from hot arid regions, 23% from hot semi-arid regions and 16% of them originated from warm sub-humid to humid regions. All other agro-ecological zones have also contributed to oilseed brassica germplasm owing to the fact that the group contains different mustards and rapeseeds occupying different niches in India resulting into locally adapted cultivars.

Out of 348 germplasm accessions of sesame crop wild relatives, 45% were collected from hot semi-arid regions, 29% from hot arid regions and 17% of them originated from hot humid per-humid regions. The germplasm accessions belonged to species *Sesamum mulayanum, Sesamum radiatum, Sesamum malabaricum, Sesamum prostratum, Sesamum alatum, Sesamum orientale, Sesamum anamalayansis,* and *Sesamum laciniatum*.

Out of 4019 germplasm accessions of chilli pepper, 39% were collected from hot semi-arid regions, 17% from warm sub-humid to humid regions and 14% of them originated from warm per-humid regions. Chilli pepper is an introduced crop species to India. Chilli genotypes have been selected by farmers over generations for agronomic and horticultural traits important to them (e.g., fruit size, heat level, colour and early maturity). As a result of a combination of natural selection and farmers' choice, well-defined landraces adapted to the specific regions viz. north eastern India, Karnataka, Andhra, etc. like Naga Jolokia, Byadagi, Guntur have evolved. These infra-specific variability allows adaptation to local conditions and resilience to climatic changes.

Out of 408 germplasm accessions of brinjal crop wild relatives, 38% were collected from hot semi-arid regions, 18% from hot humid per-humid regions, 16% from warm per-humid regions and 14% of them originated from hot sub-humid regions. The germplasm accessions belonged to species *Solanum incanum, Solanum indicum, Solanum esculentum, Solanum xanthocarpum, Solanum nigrum, Solanum aethiopicum, Solanum torvum, Solanum trilobatum, Solanum macrocarpum, Solanum viarum, Solanum incanum, Solanum gilo, Solanum spirale, Solanum insanum, Solanum capsicoides, Solanum sisymbrifolium, Solanum violaceum, Solanum virginianum, Solanum americanum* and *Solanum villosum*.

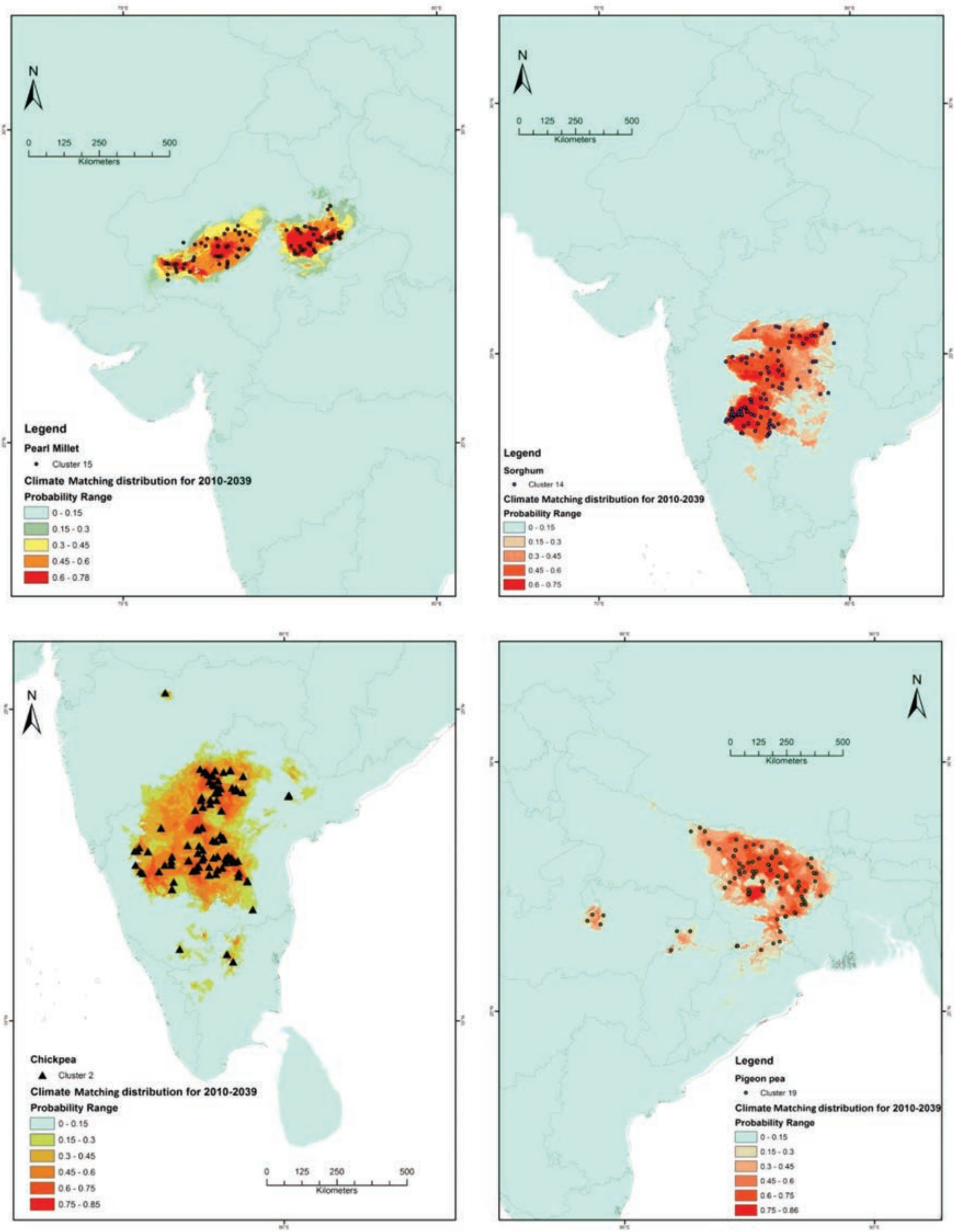


Figure 6. Examples of cimate matching in future in pearl millet, sorghum, chickpes and pigeon pea.

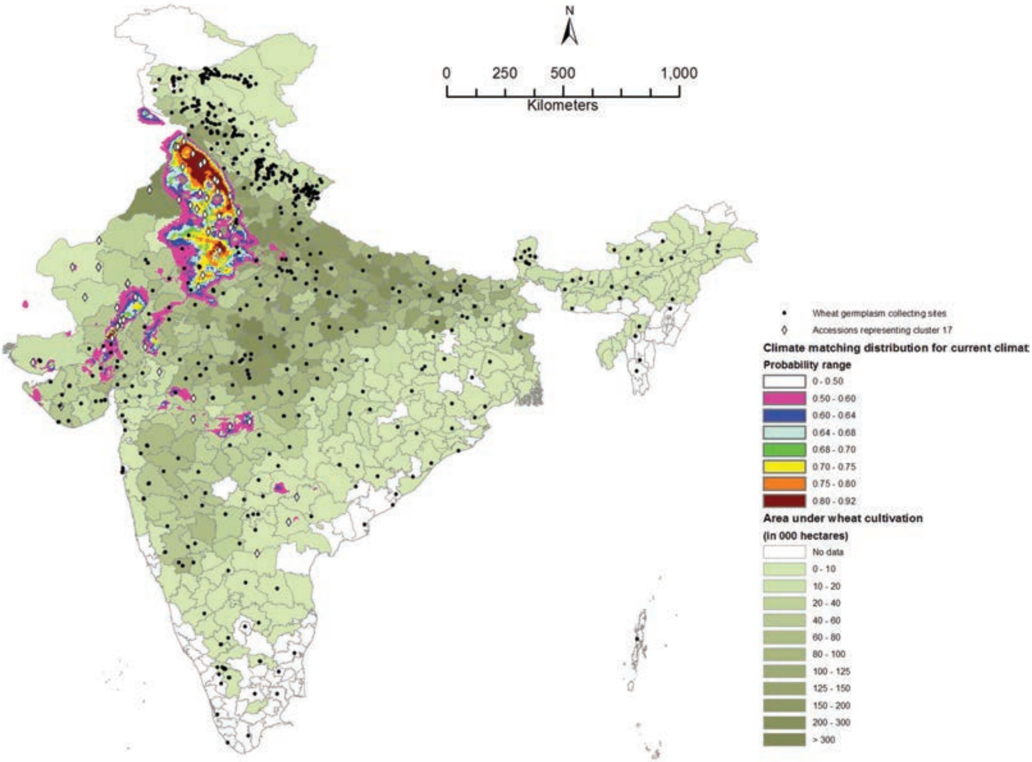


Figure 7. Examples of climate matching in future in wheat.

Georeferences indicated that 38,994 germplasm accessions of these five crops were collected from as many as 6115 sites that are non-overlapping. Sorghum accessions were collected from 1022 unique locations, wheat accessions from 834 unique locations, pigeon pea accessions from 1005 unique locations, pearl millet accessions from 2116 unique locations and chickpea accessions were collected from 1138 unique locations. Based on FloraMap[2] analysis, the statistical distribution of shared climatic variables grouped the unique locations into 20 clusters except in pearl millet where the unique locations were grouped into 27 clusters. Each cluster of Flora Map was further used as input for statistic-dependent climate matching by employing MaxEnt[3] program (www.cs.princeton.edu/~schapire/maxent/). Crop-wise results of clustering and climate matching are given in **Figure 4 and Figure 5-6**. FloraMap is a useful tool for clustering the locations based on climatic attributes (monthly rainfall totals, monthly average temperatures and monthly diurnal average range). However, the tool lacks software support and updates. If analysis requires mean rainfall or maximum temperature, or requires avoiding using day length in

[2]Jones and Gladkov (1999).FloraMap: A computer tool for predicting the distribution of plants and other organisms in the wild. CIAT, Colombia.

[3]Phillips et al (2006). Maximum entropy modeling of species geographic distributions.Ecol Model 190:231–259.

the analysis, it cannot be done. Results of MaxEnt provided no additional advantages over control (image dependent deductions of climate matches) for the number of variables (only mean maximum temperature) studied. Therefore, FloraMap and MaxEnt based analyses were not repeated in second set of five crops.

Mapping germplasm collection sites on current and future temperature regimes

Based on the current data (1950–2000) of temperature distribution at the sites of collection, the range of mean maximum temperatures observed within the crop season of each target crop was determined. Collection sites were categorized into temperature class intervals of 2 °C. Areas experiencing each class were delineated on India's map for current (1950–2000) and future (2010-2039) climates. Climate maps are given crop-wise in the next section.The maps indicated that change in temperature regimes in each crop would be imminent. Overall, it was observed that changes in the maximum temperatures would be pronounced in *rabi* season, and in spite of having overall higher temperatures, extent of change from current to immediate future in *kharif* season would be less. It may be noted that the figures are not the areas under cultivation but areas depicting crop occurrence based on the germplasm collection data. The figures expressed as areas are per cent of total geographical area.

The climates maps of each crop indicated that change in temperature regimes in each crop would be imminent. The lost areas to higher temperature often belong to most optimum temperature regimes.

Figure 8. summarizes and illustrates the extent and direction of change in area from current climate (1950-2000) to future climate (2010-2039) across different temperature classes for each of the ten crop species. It was observed that the lost areas in each crop often belonged to the most optimum temperature regimes for respective crop species. There was no apparent gain in the areas suitable for cultivation. The change in the area was overlapped with change in the actual number of collection sites in different temperature regimes. This would offset the generalization of inferences based on area change alone as there can be areas where the germplasm may not occur. The information on change observed in the temperature regimes of collection sites would also add to interpretations based on the predictions. For instance, in wheat, change based on collection sites showed two clear loss-gain pairs one each for cooler north-western plains (26-28 °C) and central and peninsular zones (30-32 °C). The change based on collection sites also amplified the effects of otherwise minor changes observed in kharif crops. For instance in pigeon pea, changes in the areas up to 15% has an effect of changes in the temperature classes of germplasm collection sites up to 50%.

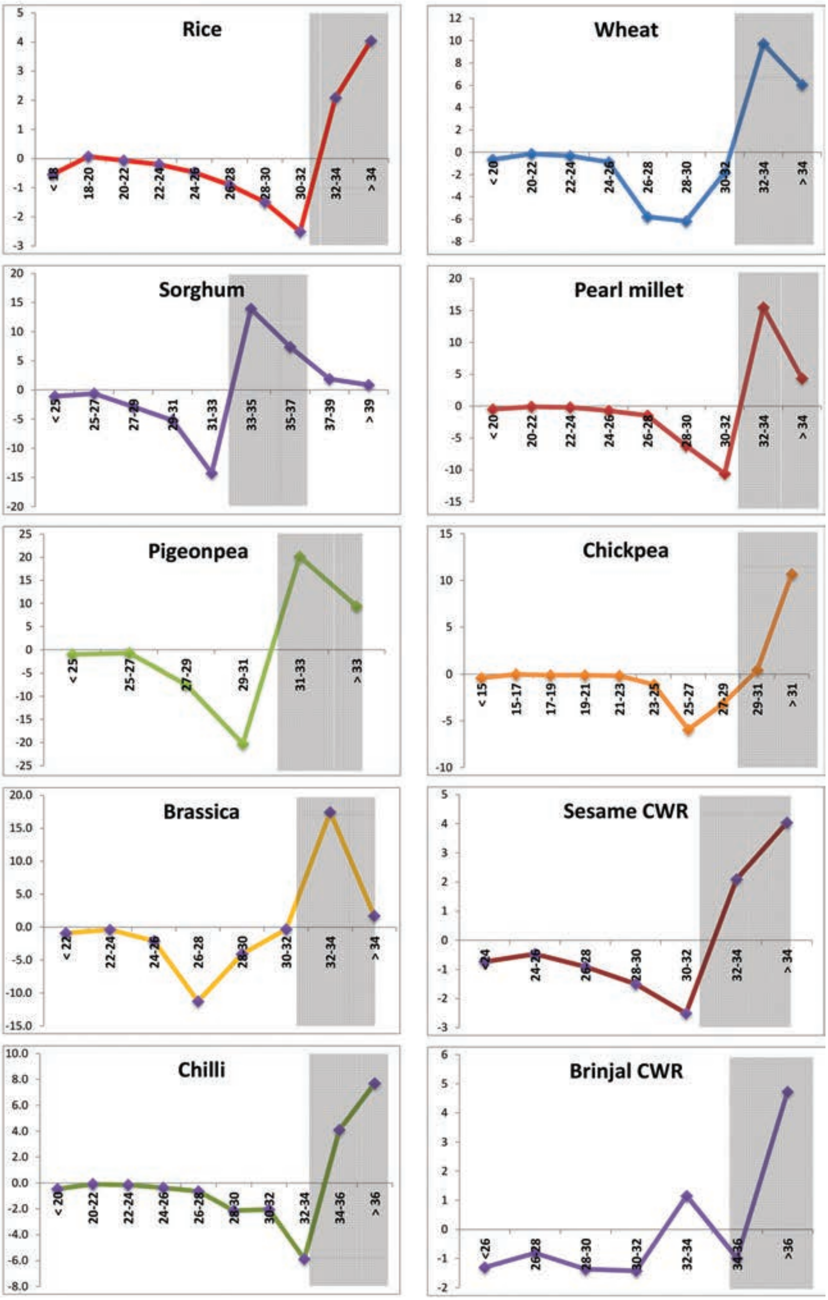


Figure 8. Change in the area under different temperature regimes (reflected by monthly mean maximum temperature) in ten crops during crop seasons. Change in area from current climate (1950-2000) to future climate (2010-2039) is expressed in percent (on y-axis) across different temperature classes (on x-axis) specific to a crop. Note that the lost areas often belong to the most optimum temperature regimes.

PGR Climate Atlas

Wheat	Rice
Sorghum	Oilseed brassica
Pearl millet	Sesame CWR
Chickpea	Chilli pepper
Pigeon pea	Brinjal CWR

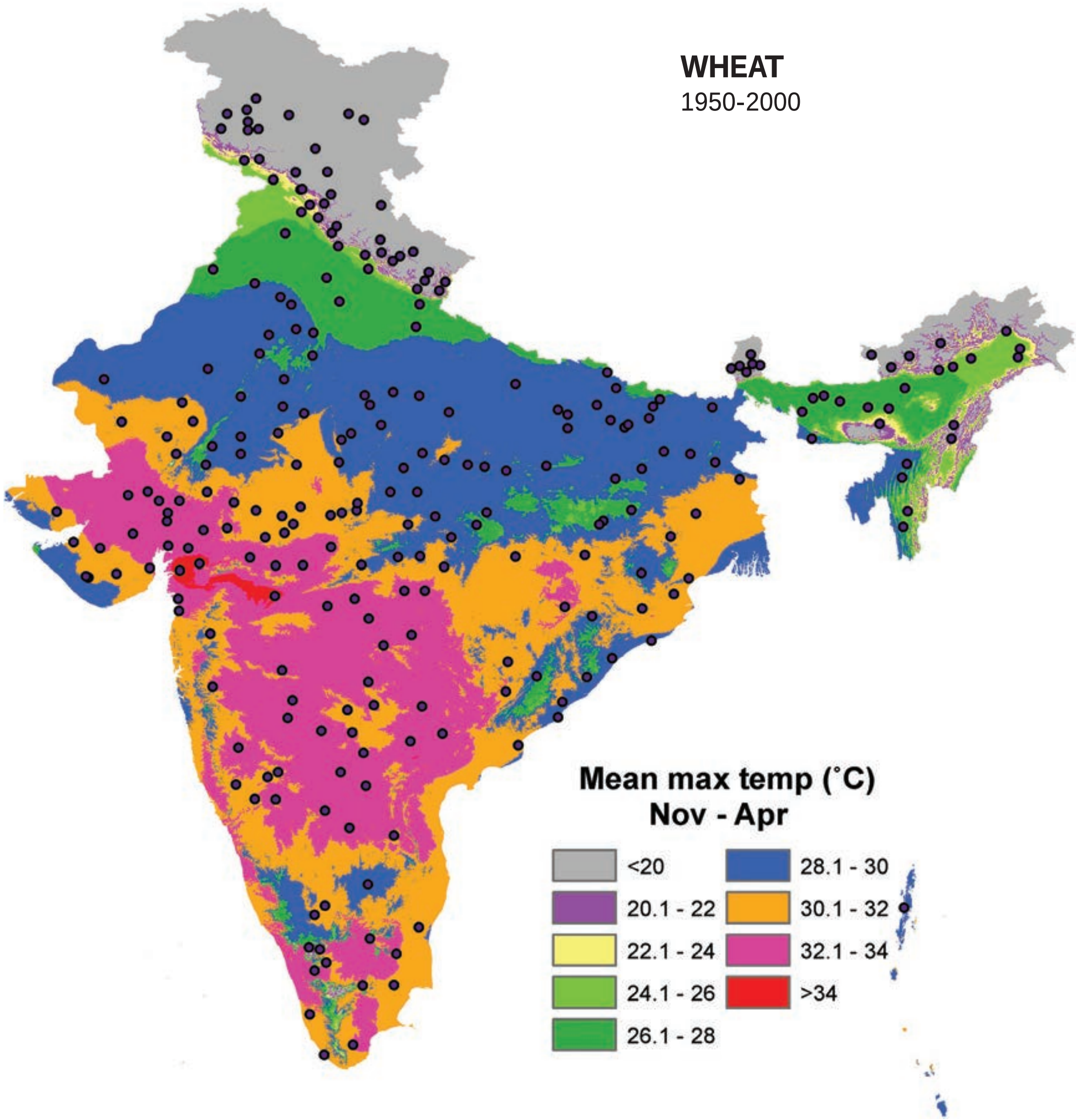


Figure 9: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for wheat for Nov-Apr season to identify vulnerable locations and areas with pre-adapted germplasm.

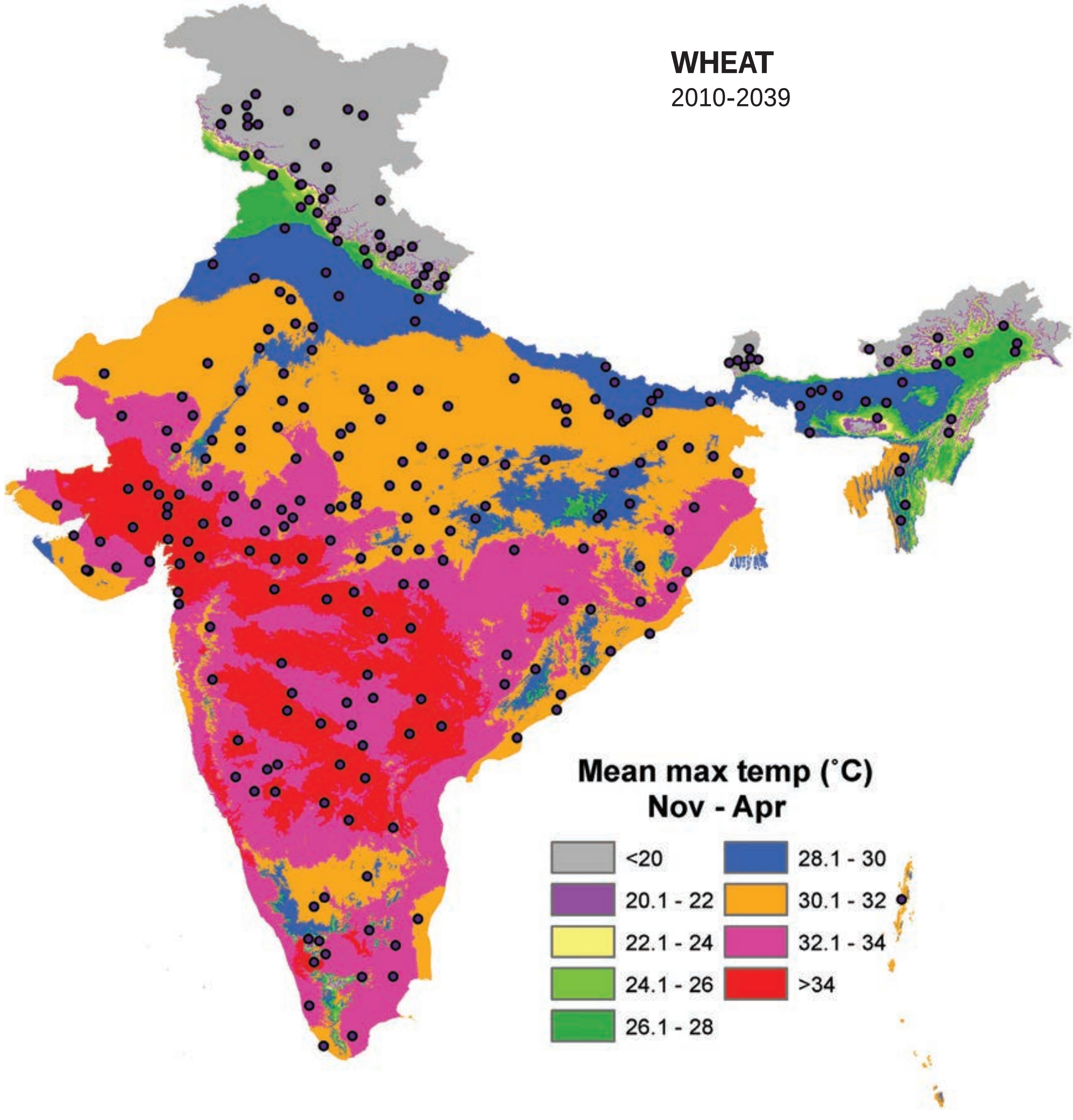


Figure 10: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for wheat for Nov-Apr season to identify vulnerable locations and areas with pre-adapted germplasm

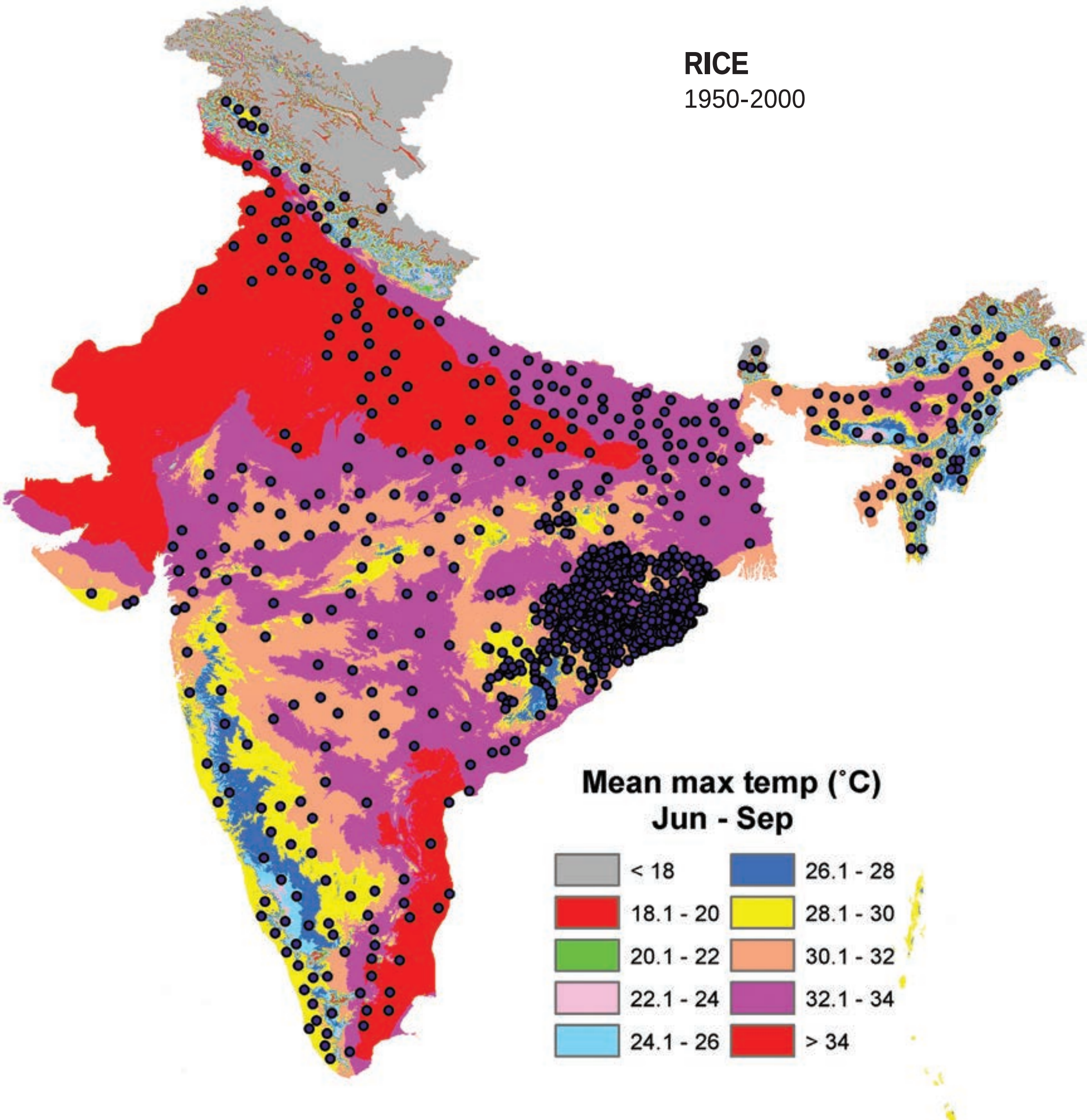


Figure 11: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for rice for Jun-Sept season to identify vulnerable locations and areas with pre-adapted germplasm.

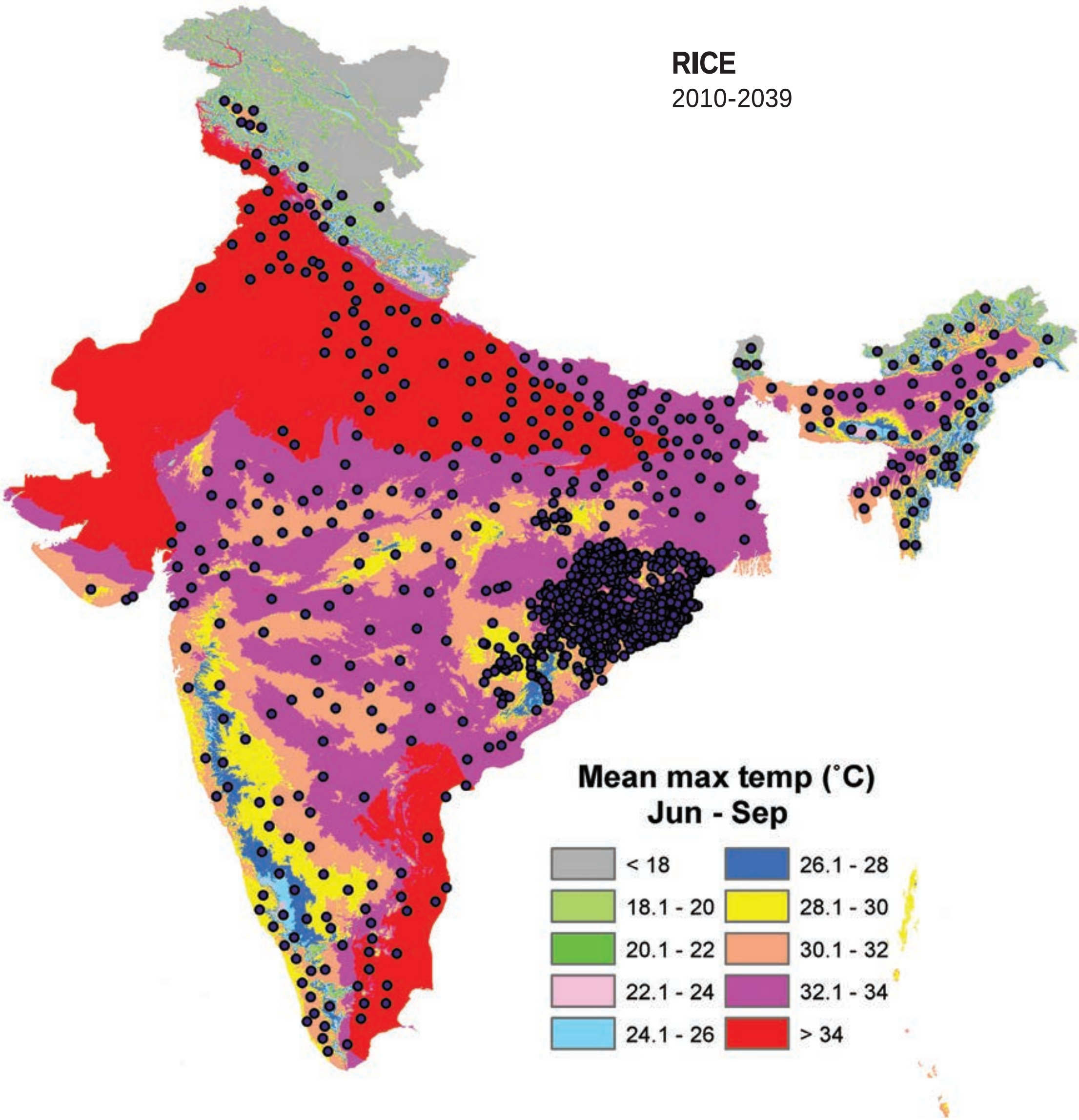


Figure 12: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for rice for Jun-Sept season to identify vulnerable locations and areas with pre-adapted germplasm.

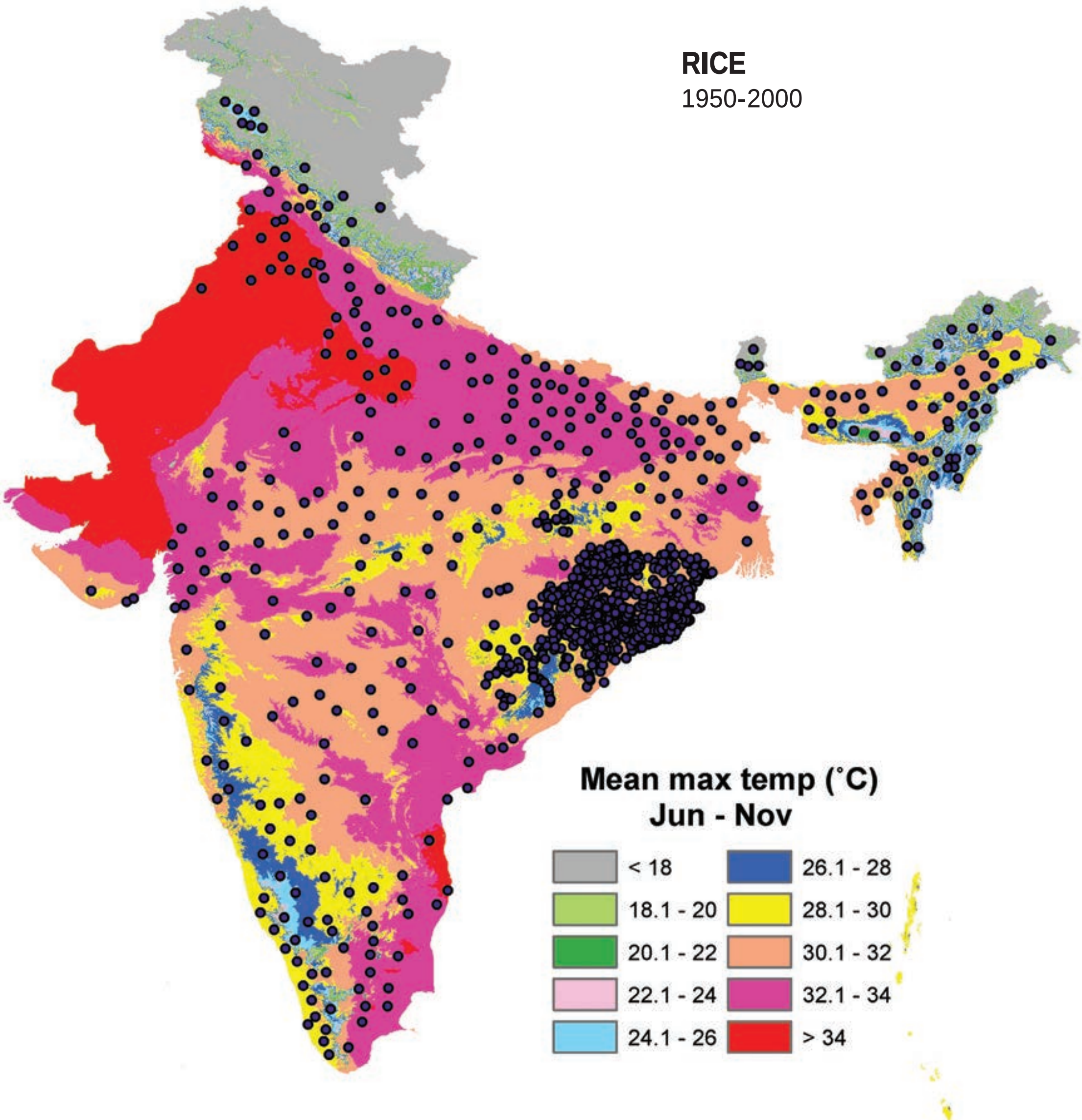


Figure 13: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for rice for Jun-Nov season to identify vulnerable locations and areas with pre-adapted germplasm.

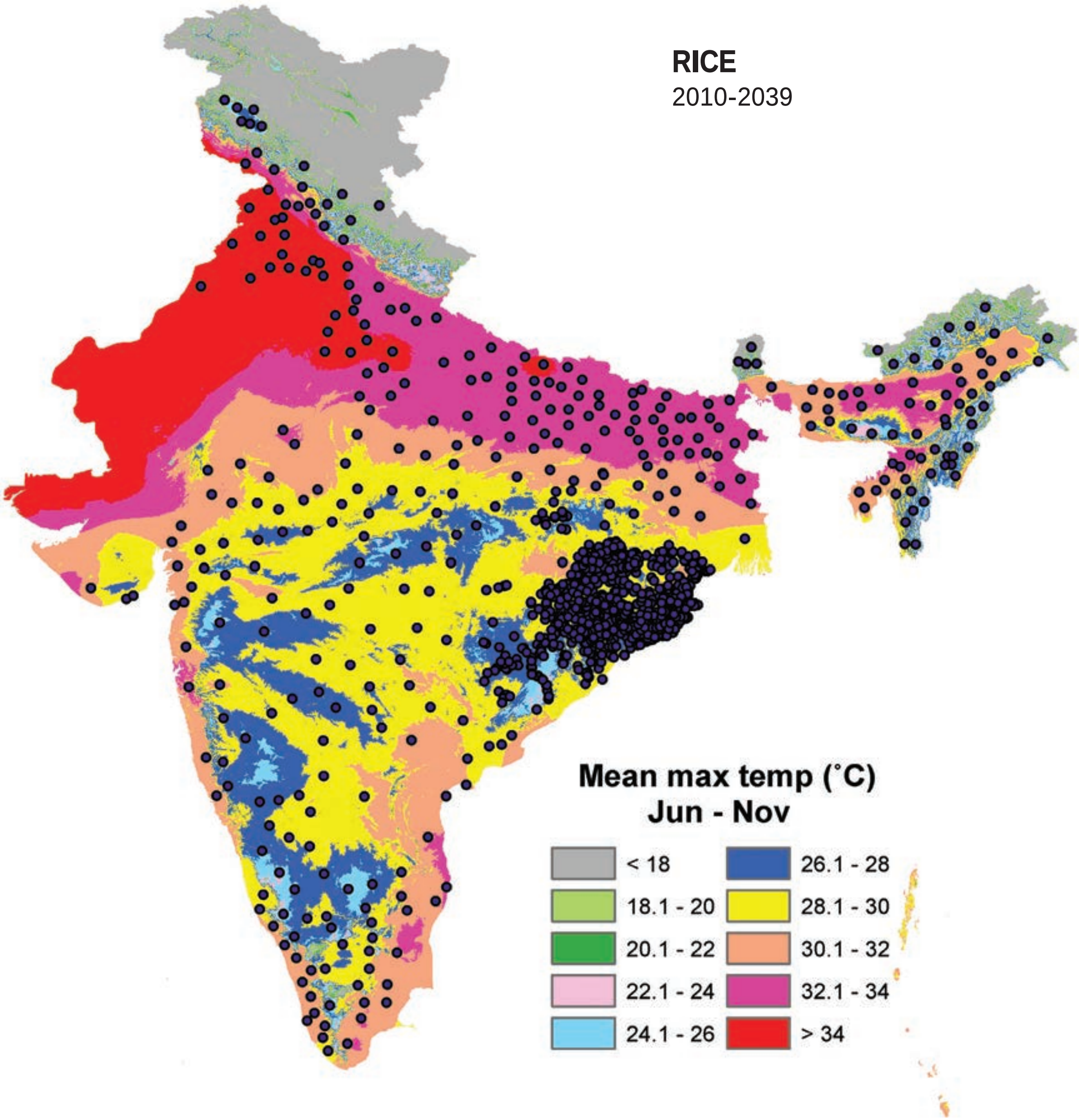


Figure 14: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for rice for Jun-Nov season to identify vulnerable locations and areas with pre-adapted germplasm.

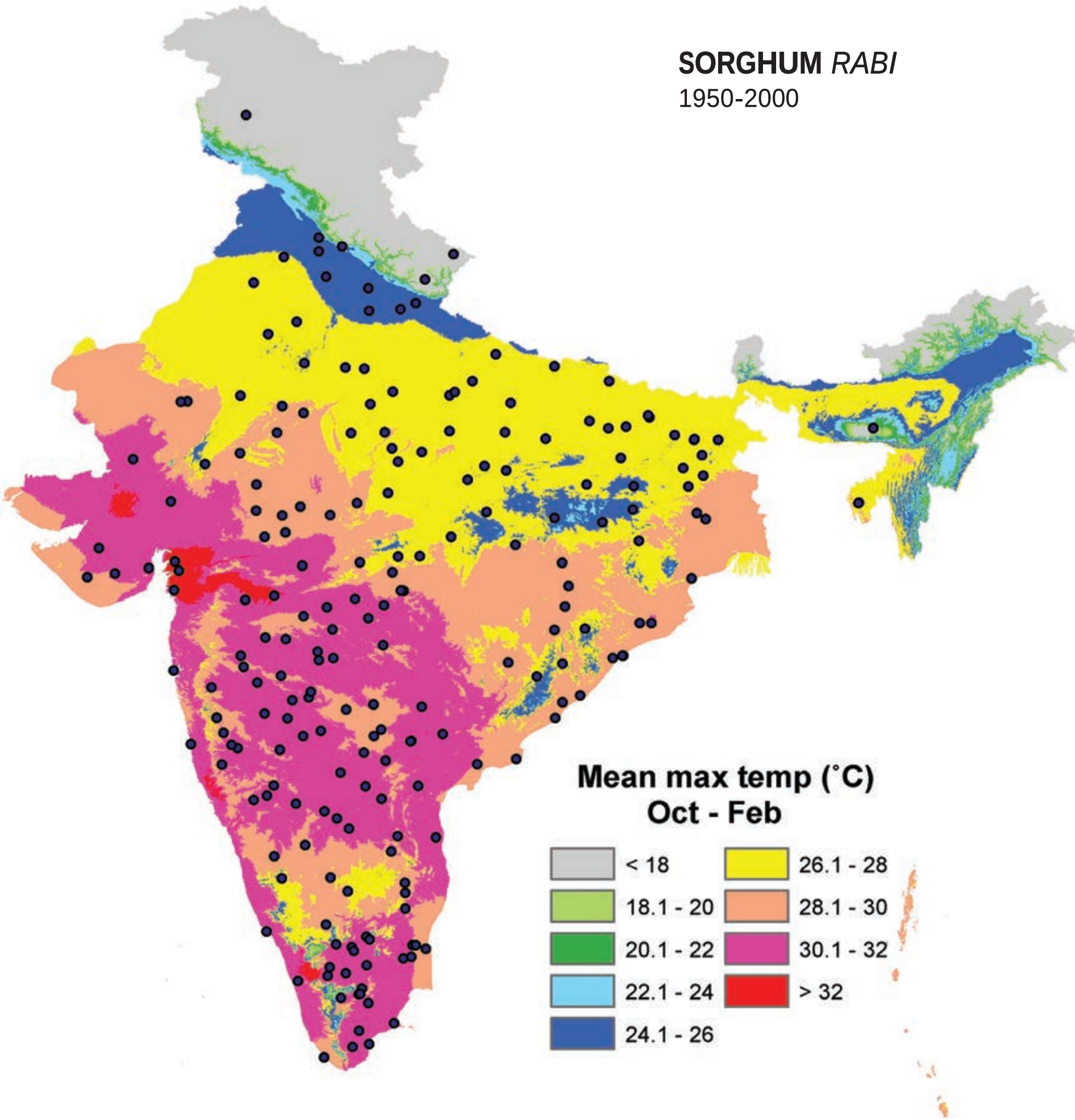


Figure 15: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for *rabi* sorghum for Oct-Feb season to identify vulnerable locations and areas with pre-adapted germplasm.

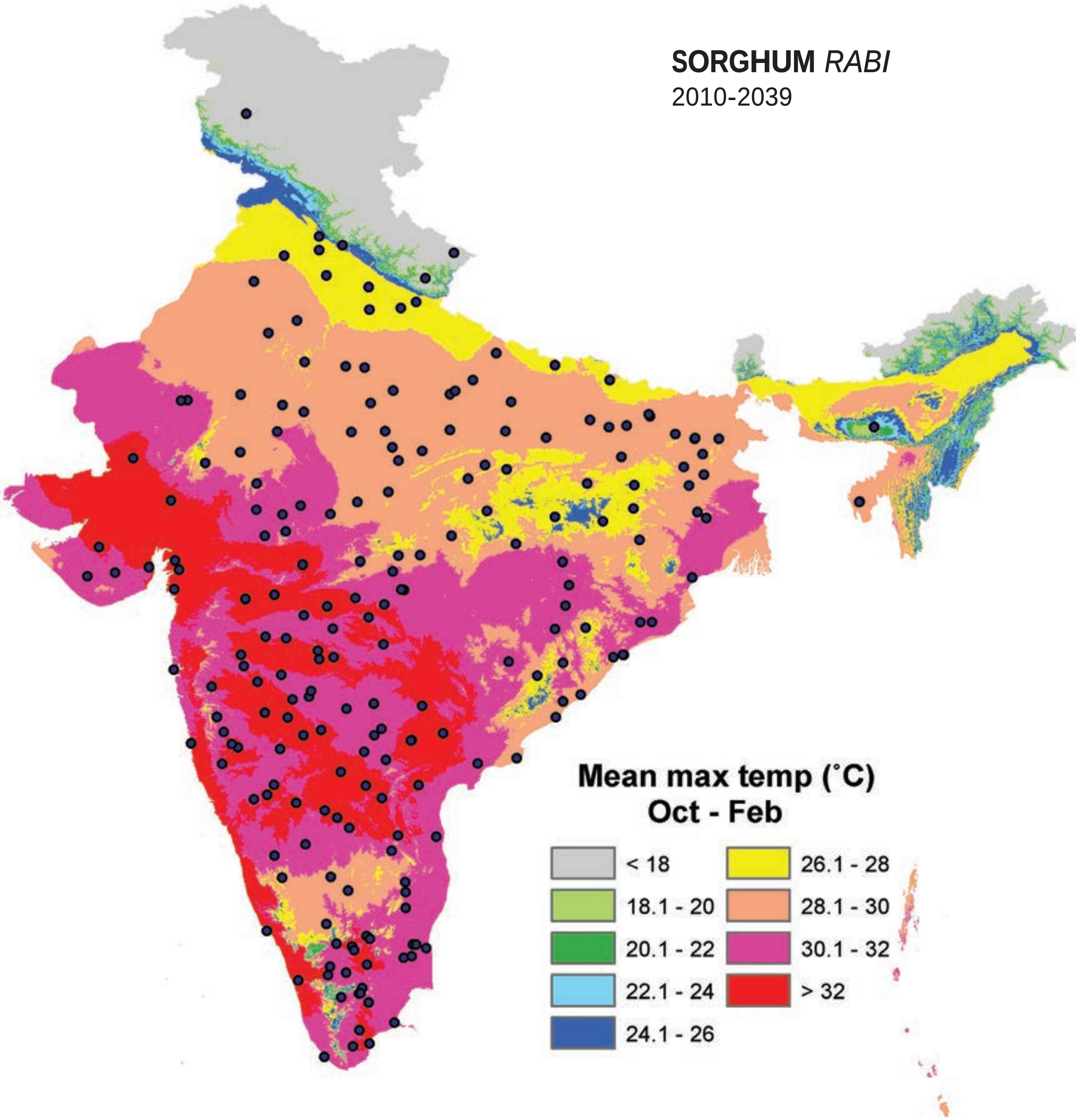


Figure 16: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for *rabi* sorghum for Oct-Feb season to identify vulnerable locations and areas with pre-adapted germplasm.

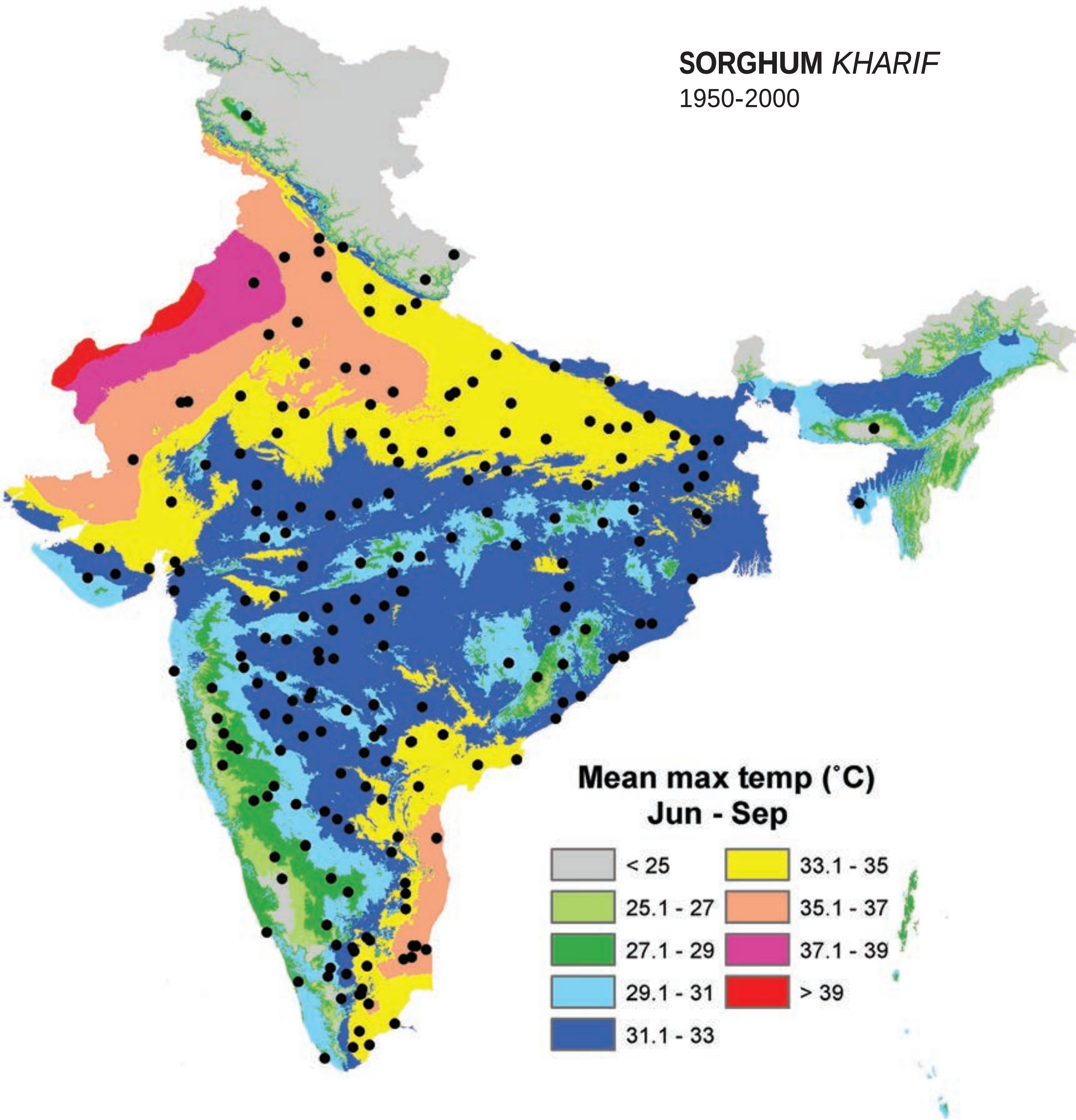


Figure 17: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for *kharif* sorghum for Jun-Sept season to identify vulnerable locations and areas with pre-adapted germplasm.

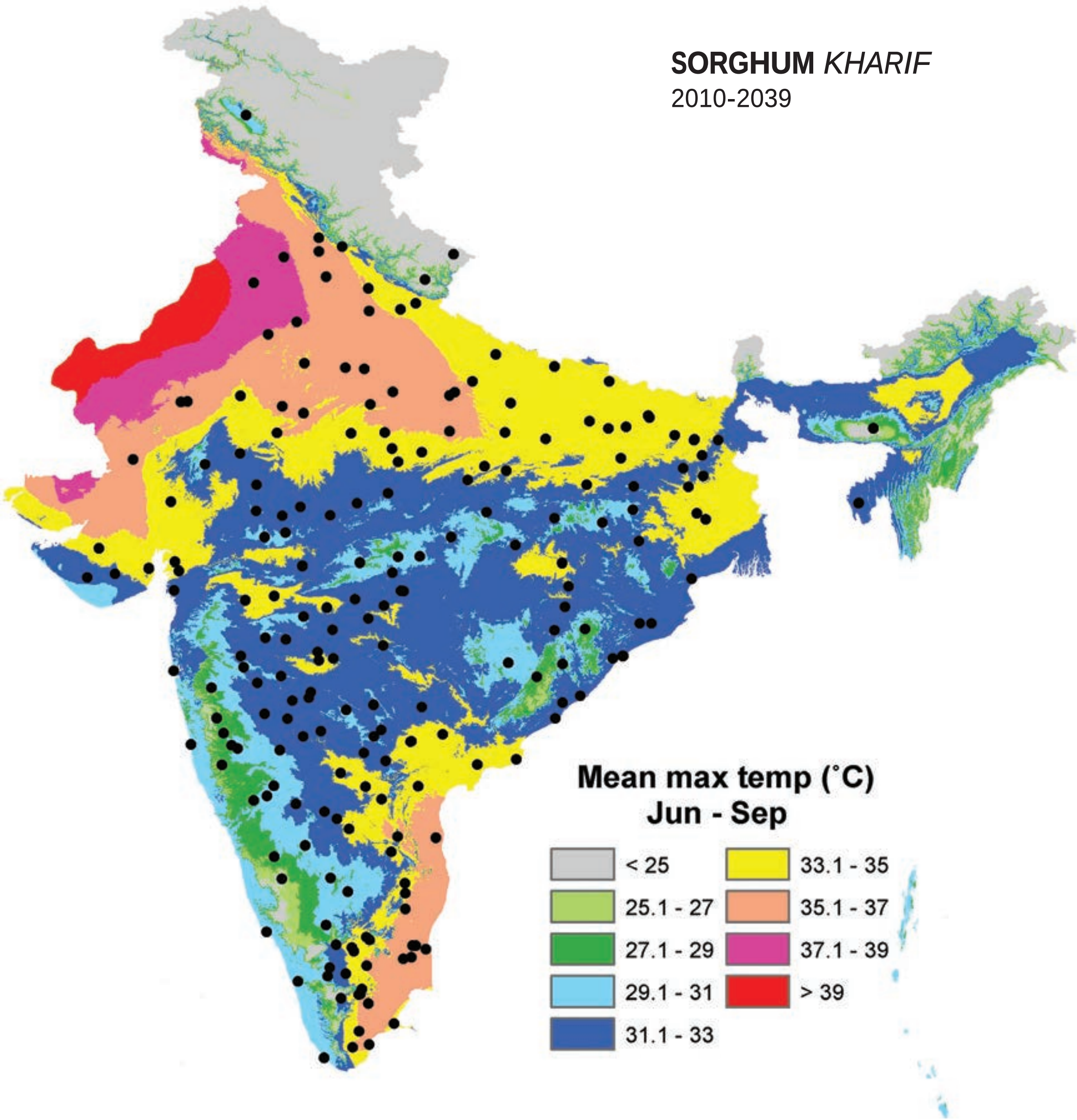


Figure 18: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for *kharif* sorghum for Jun-Sept season to identify vulnerable locations and areas with pre-adapted germplasm.

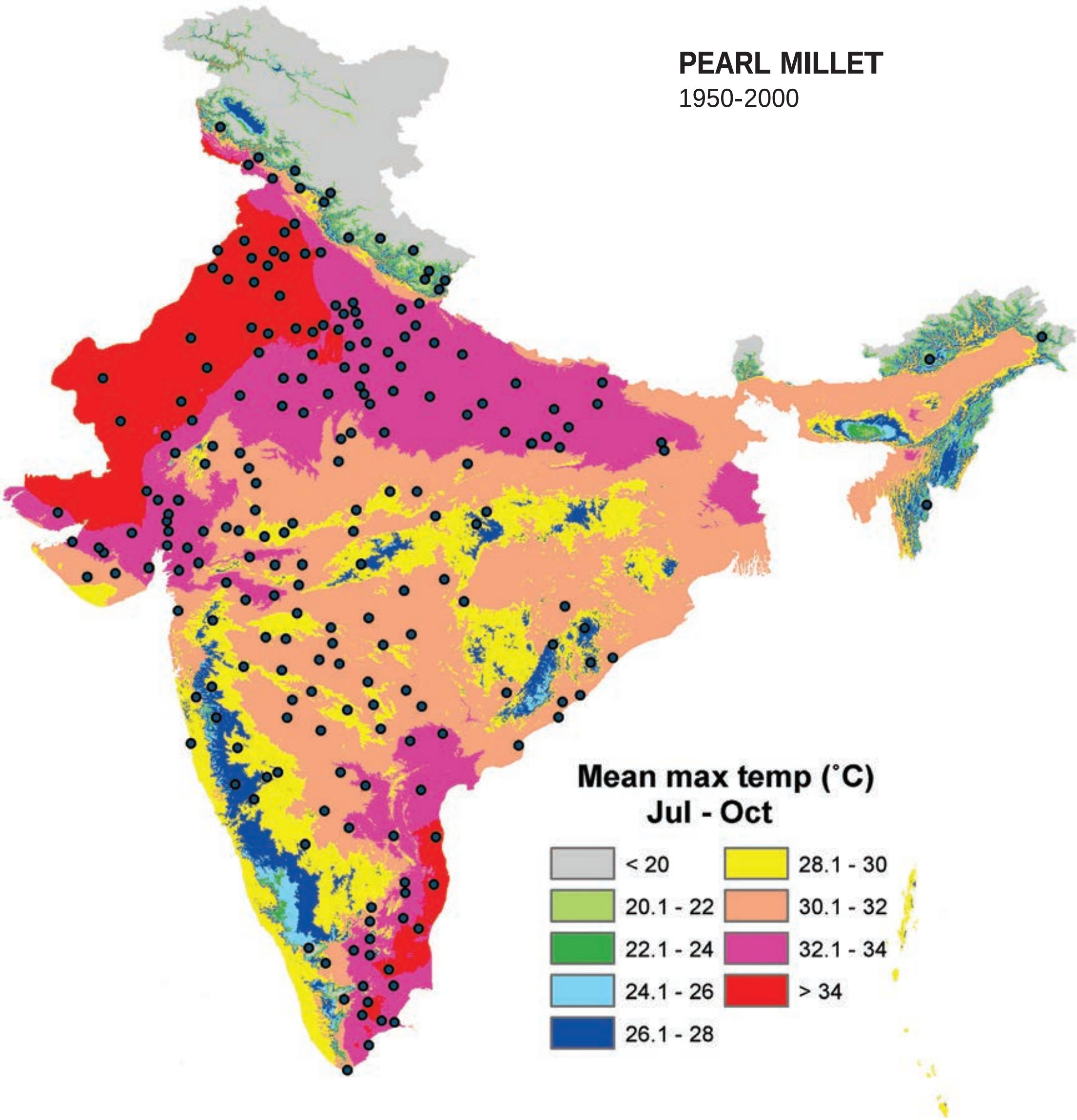


Figure 19: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for pearl millet for Jul-Oct season to identify vulnerable locations and areas with pre-adapted germplasm.

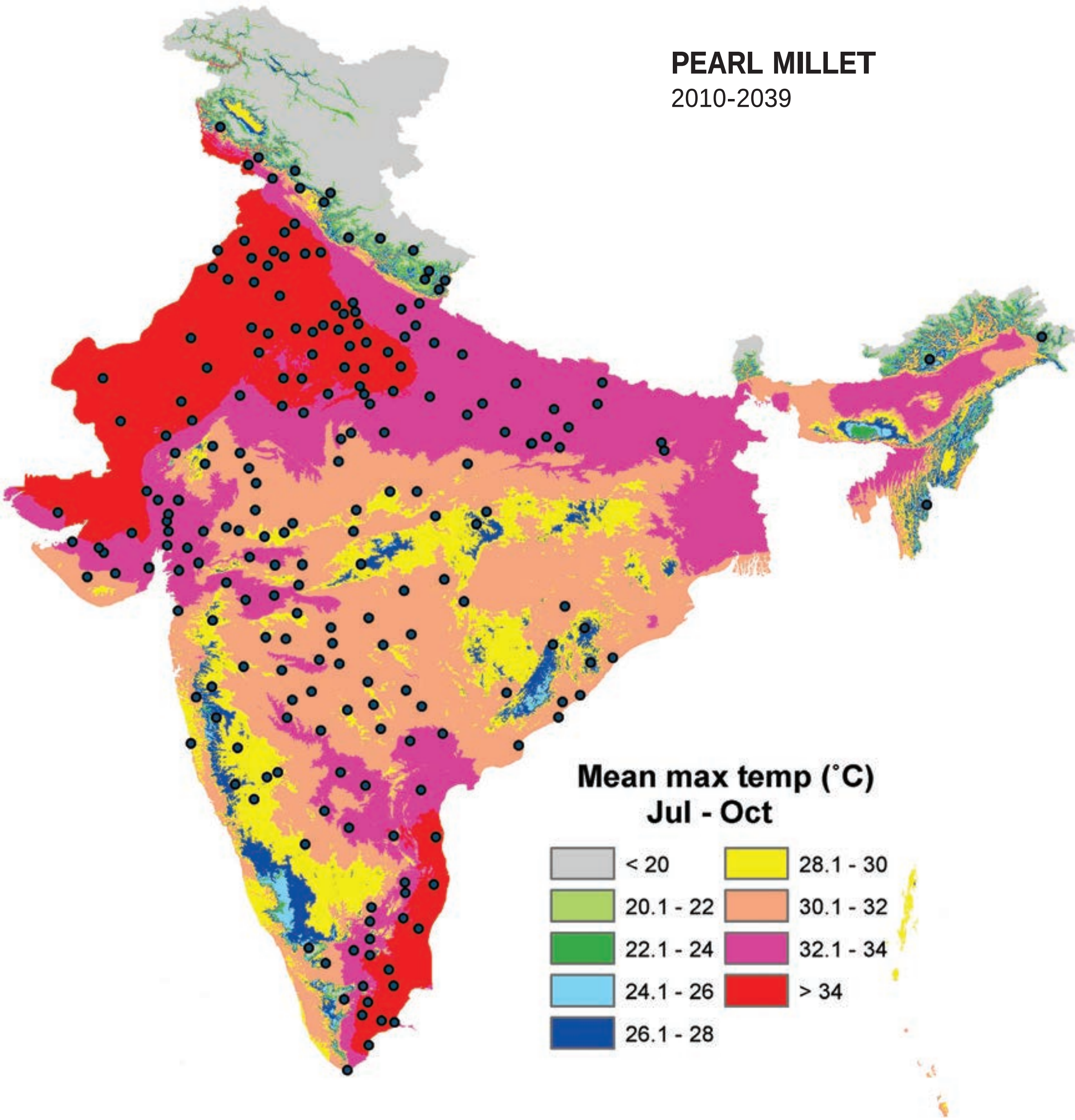


Figure 20: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for pearl millet for Jul-Oct season to identify vulnerable locations and areas with pre-adapted germplasm.

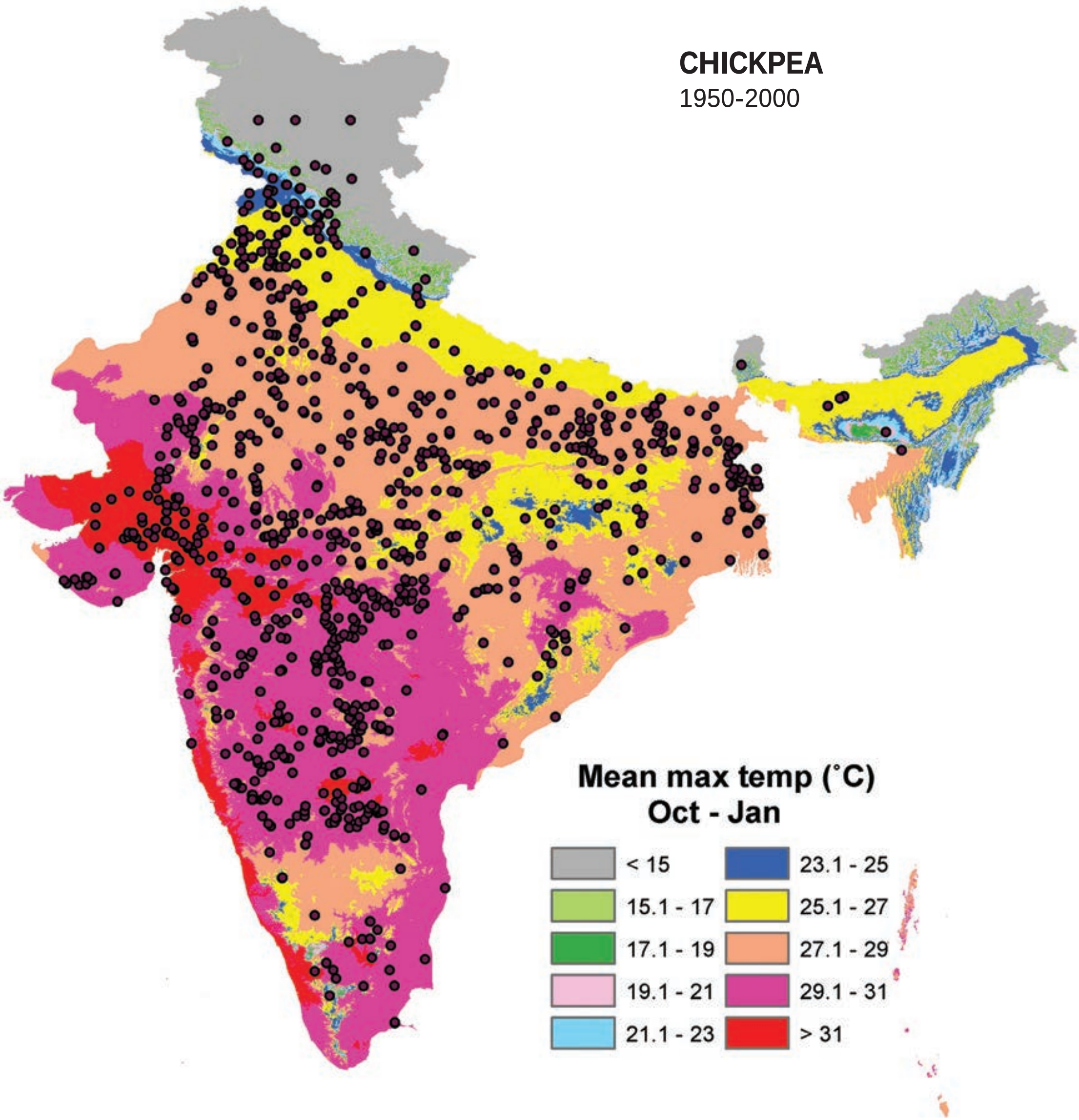


Figure 21: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for chickpea for Oct-Jan season to identify vulnerable locations and areas with pre-adapted germplasm

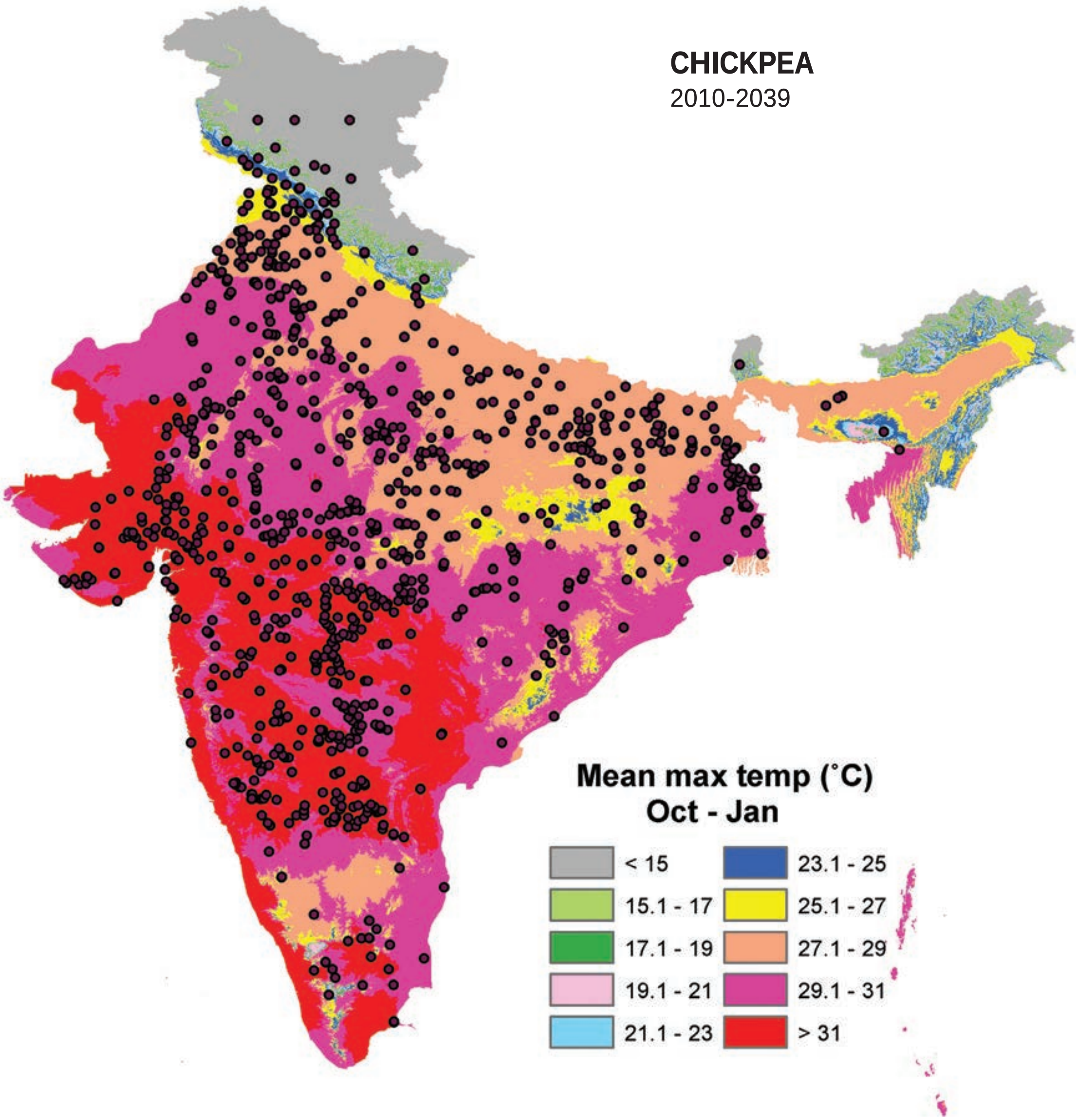


Figure 22: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for chickpea for Oct-Jan season to identify vulnerable locations and areas with pre-adapted germplasm.

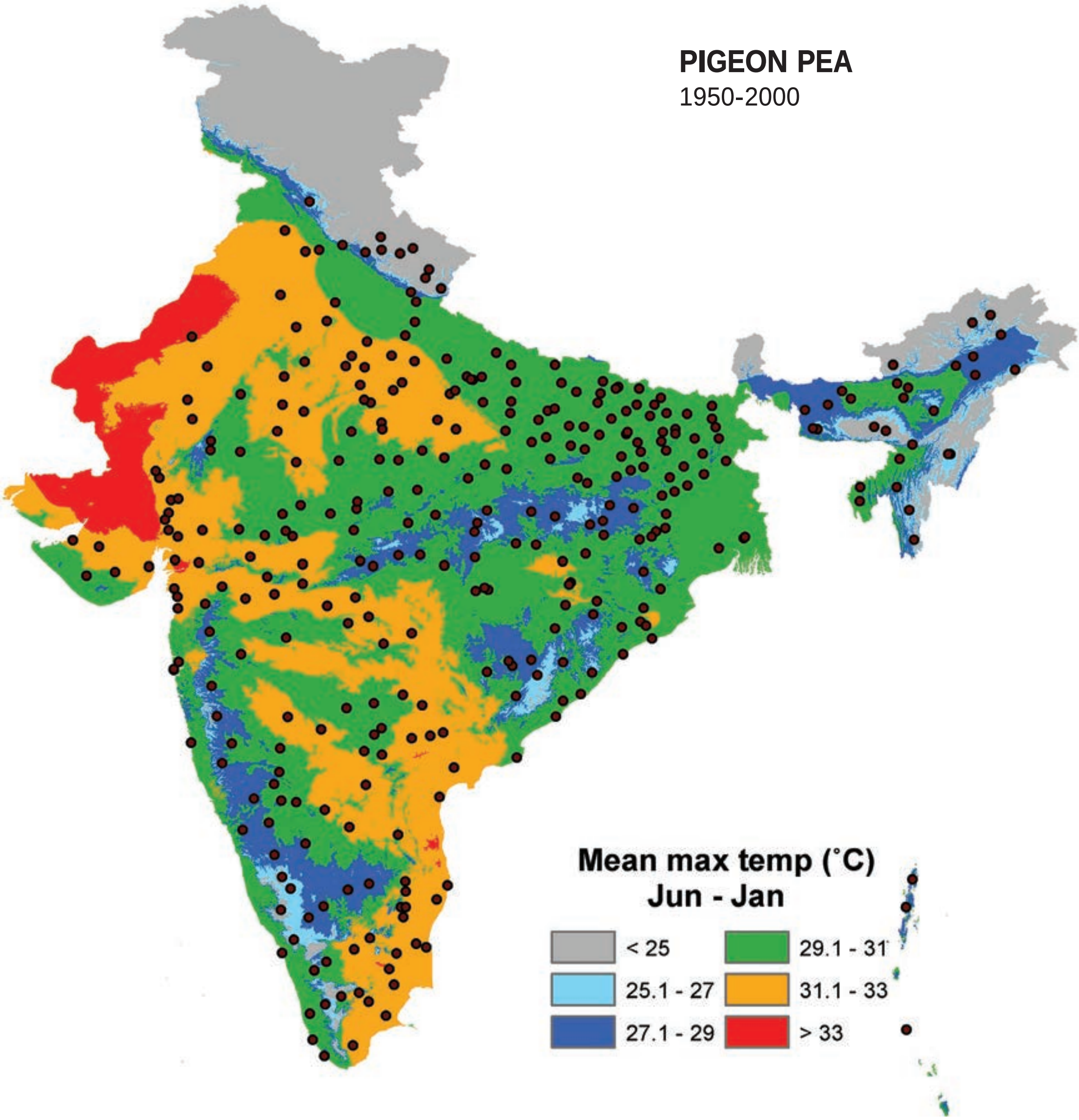


Figure 23: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for pigeon pea for Jun-Jan season to identify vulnerable locations and areas with pre-adapted germplasm.

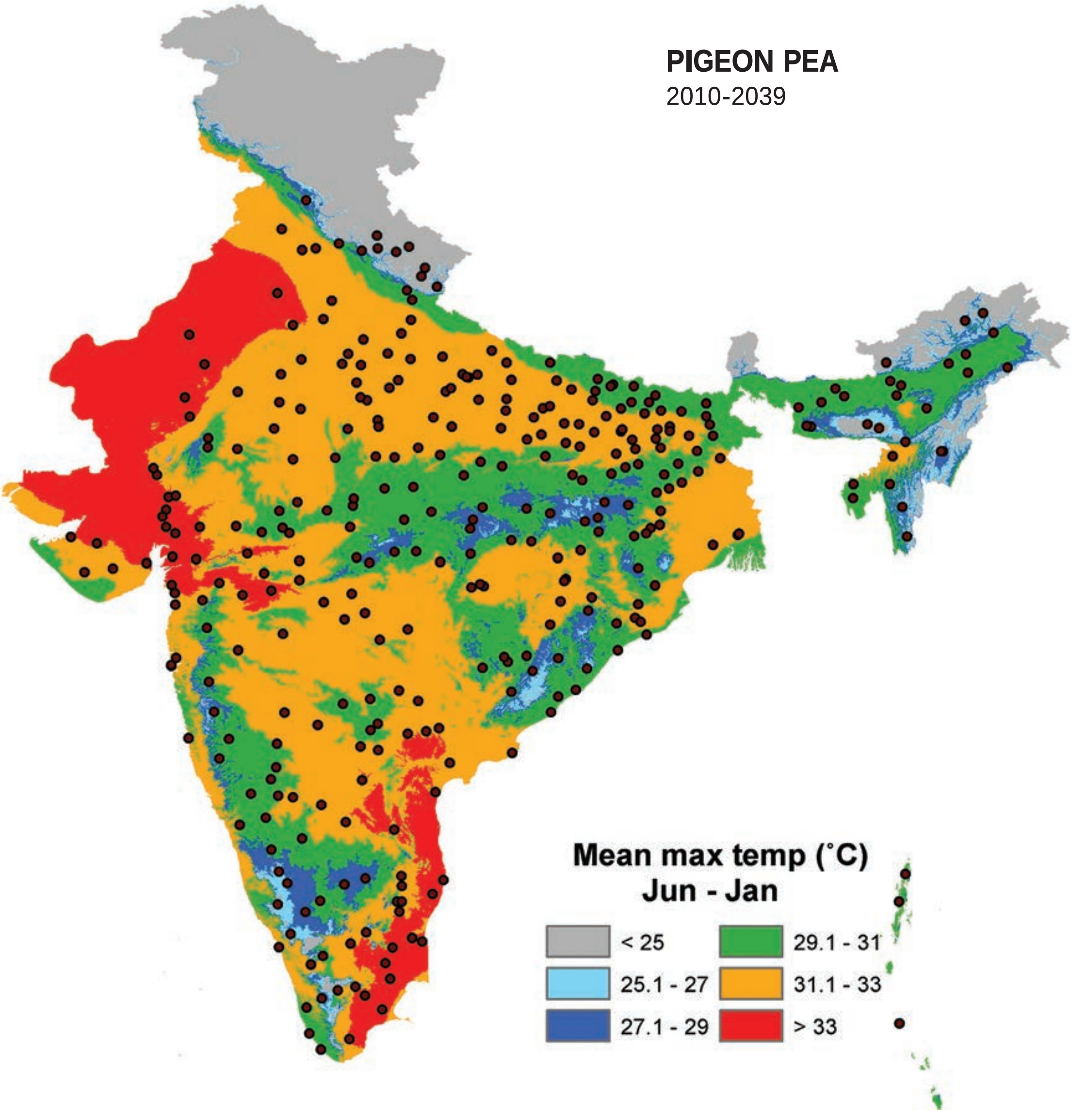


Figure 24: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for pigeon pea for Jun-Jan season to identify vulnerable locations and areas with pre-adapted germplasm.

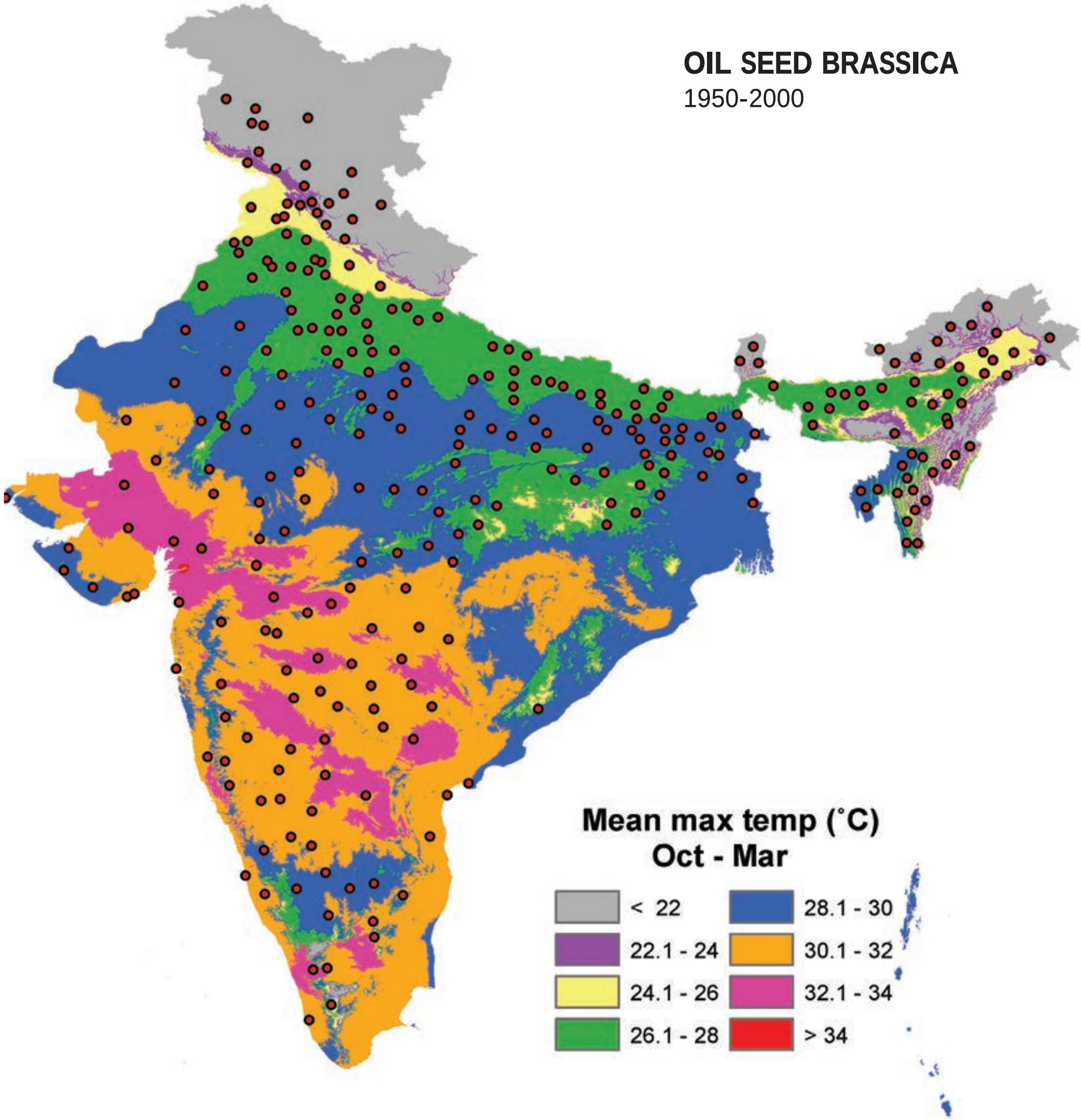


Figure 25: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for oil seed brassica for Oct-Mar season to identify vulnerable locations and areas with pre-adapted germplasm.

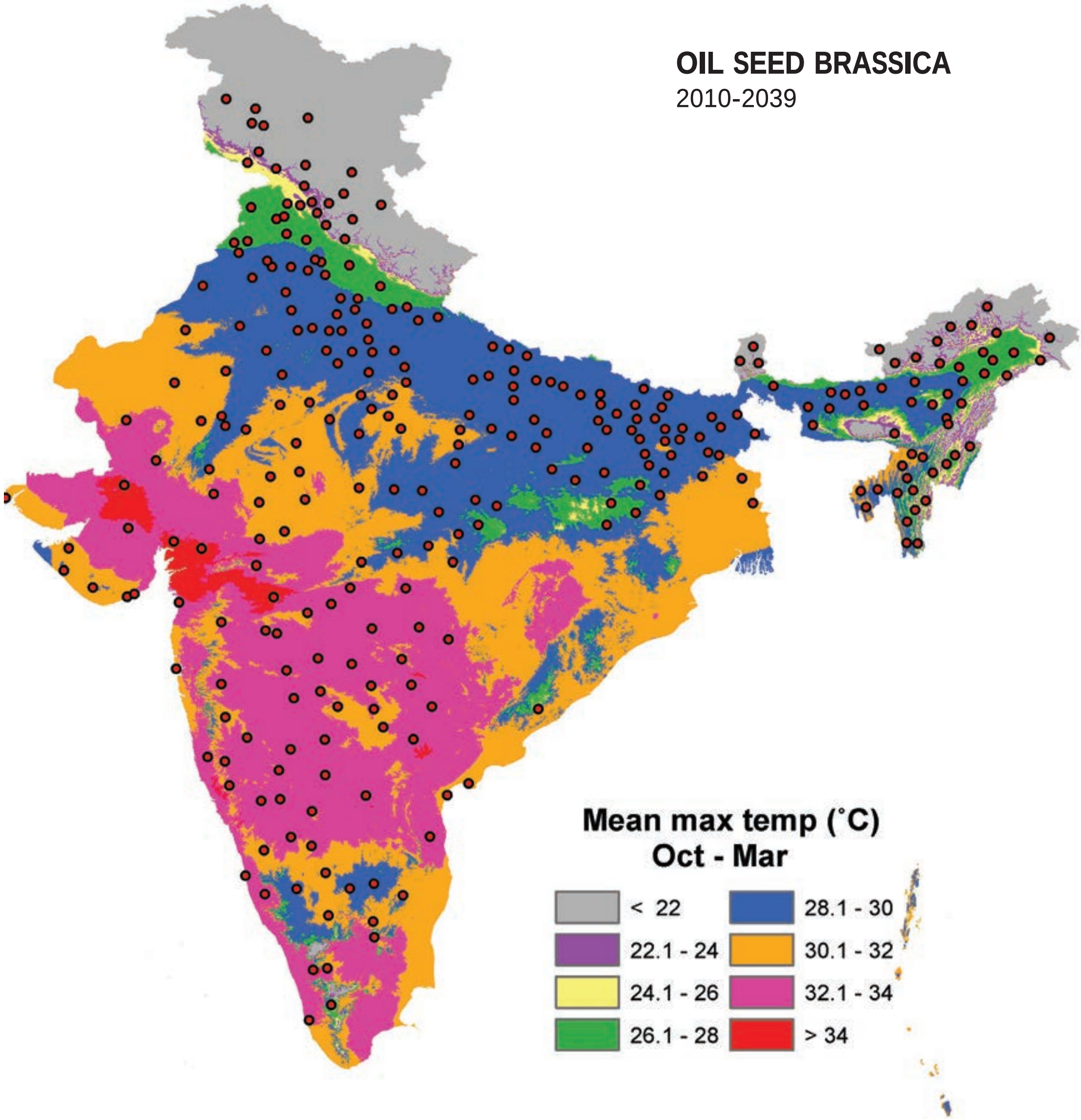


Figure 26: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for oil seed brassica for Oct-Mar season to identify vulnerable locations and areas with pre-adapted germplasm.

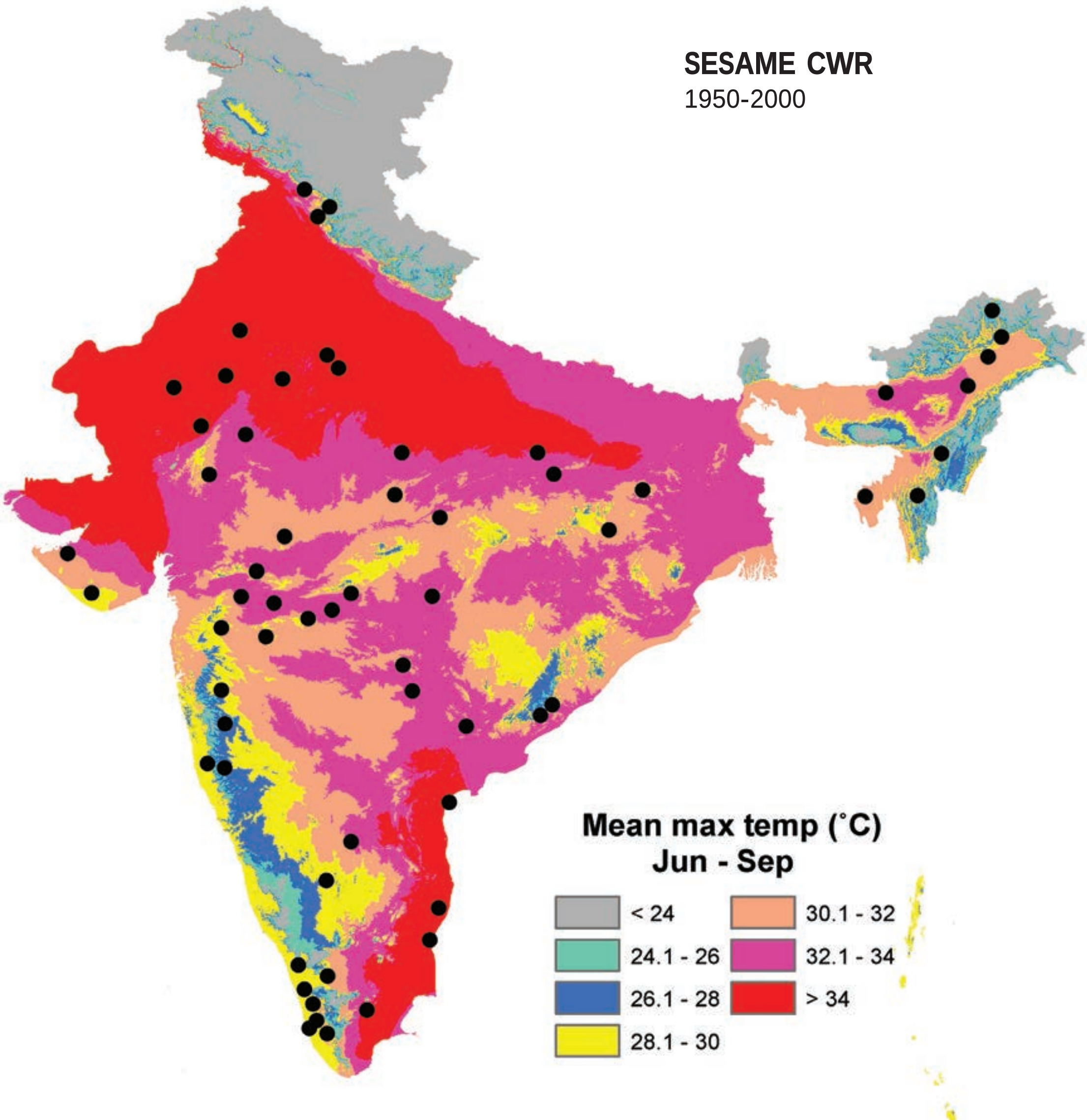


Figure 27: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for sesame CWR for Jun-Sept season to identify vulnerable locations and areas with pre-adapted germplasm.

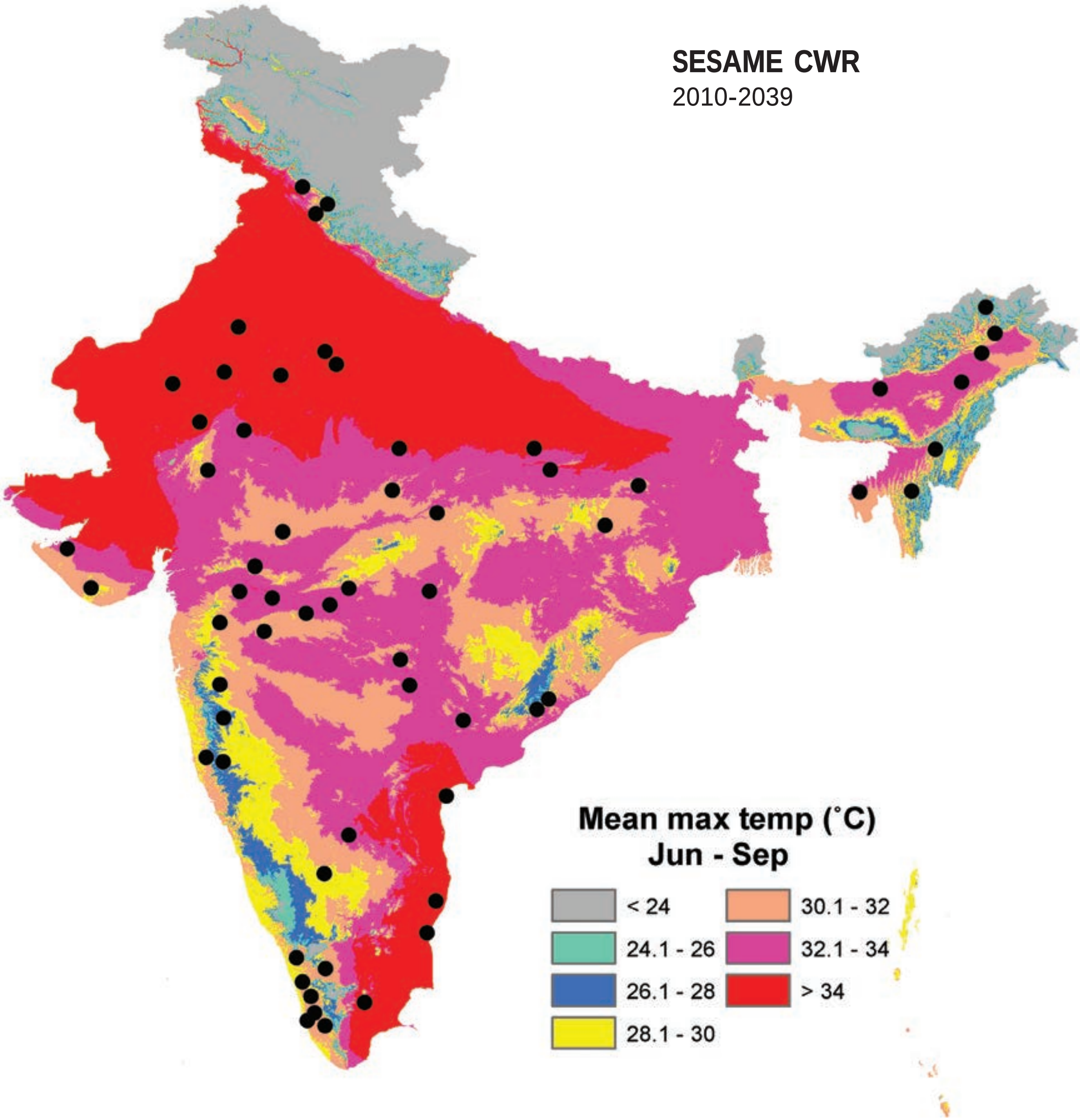


Figure 28: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for sesame CWR for Jun-Sept season to identify vulnerable locations and areas with pre-adapted germplasm.

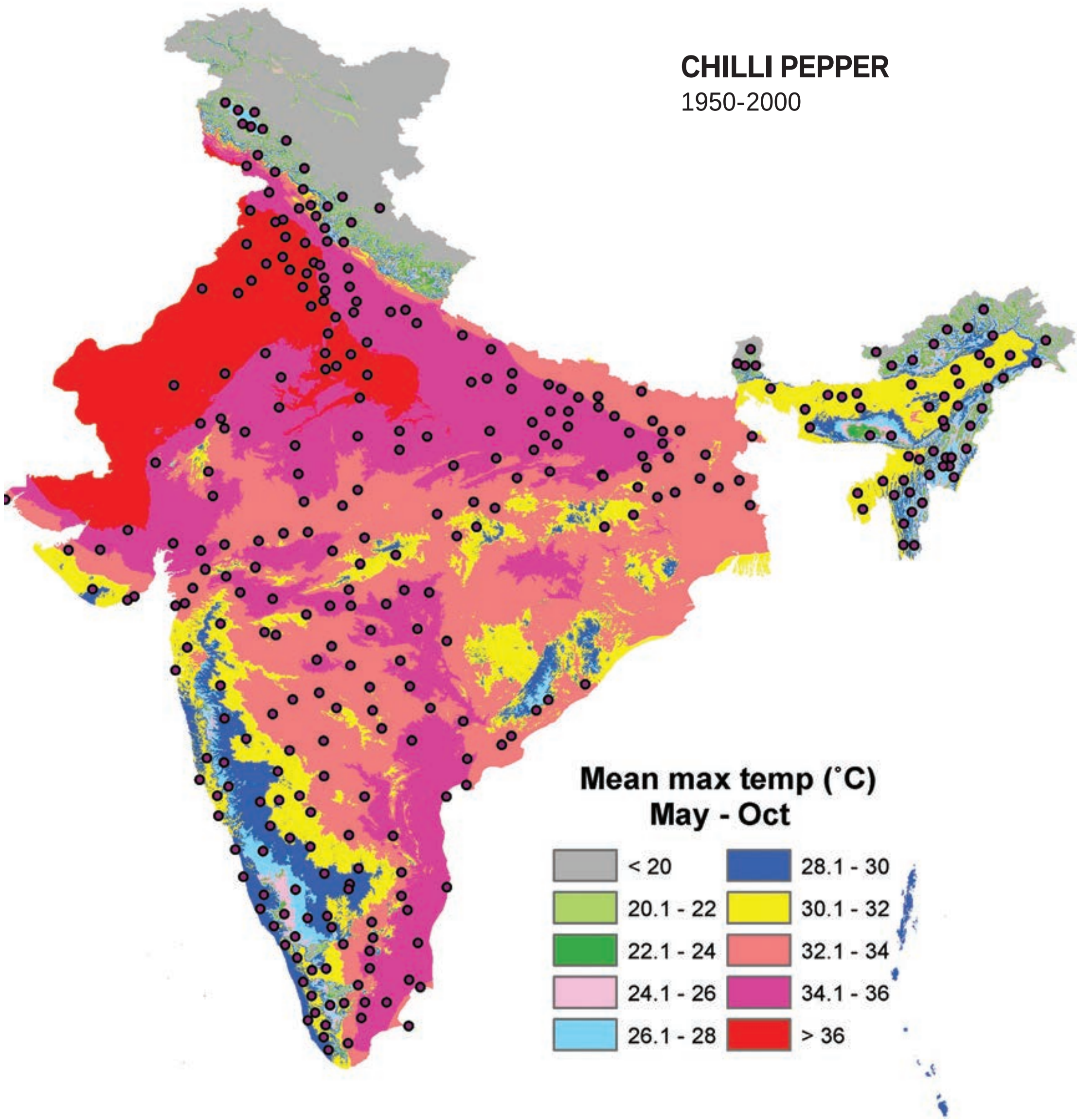


Figure 29: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for chilli pepper for May-Oct season to identify vulnerable locations and areas with pre-adapted germplasm.

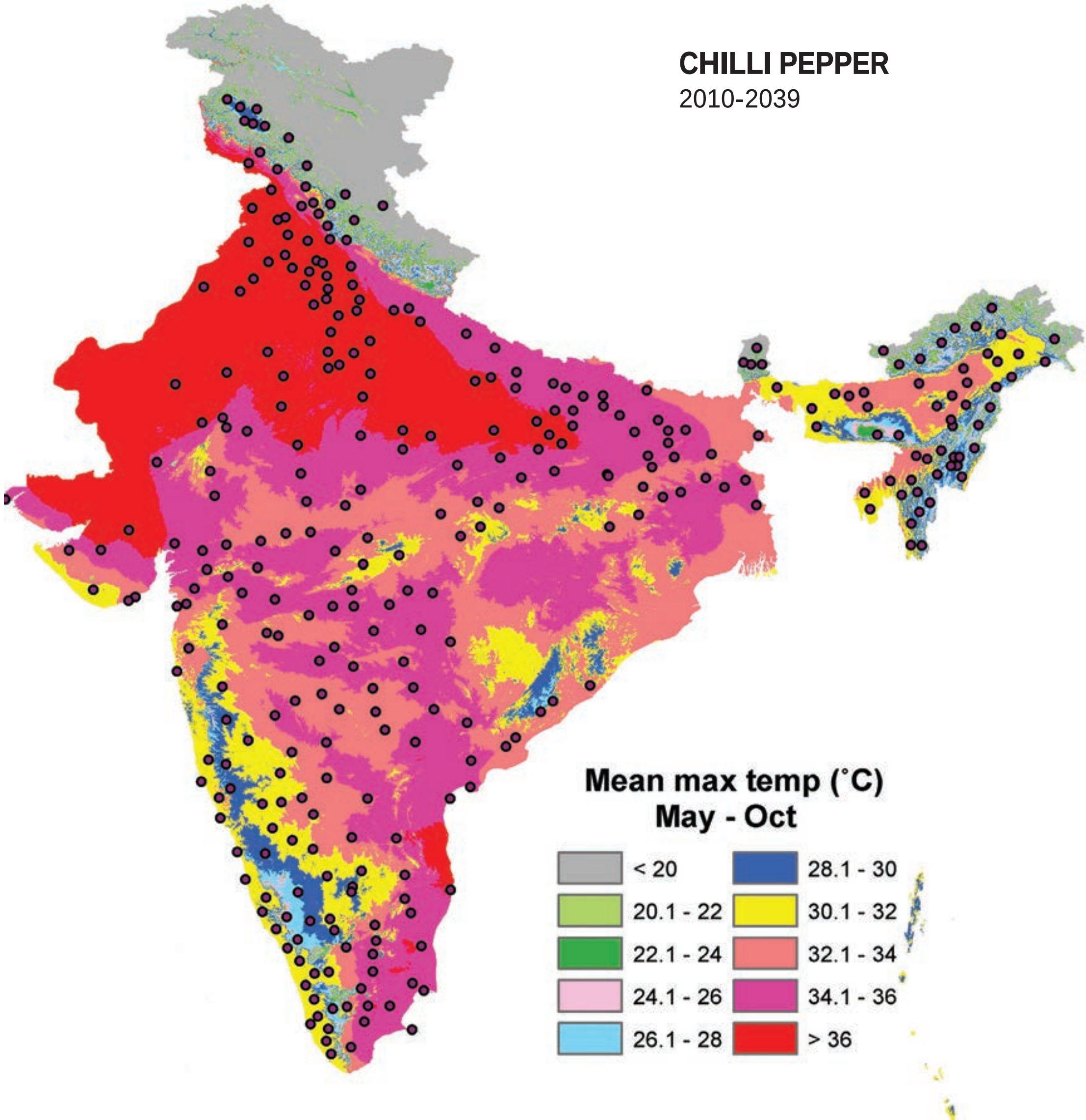


Figure 30: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for chilli pepper for May-Oct season to identify vulnerable locations and areas with pre-adapted germplasm.

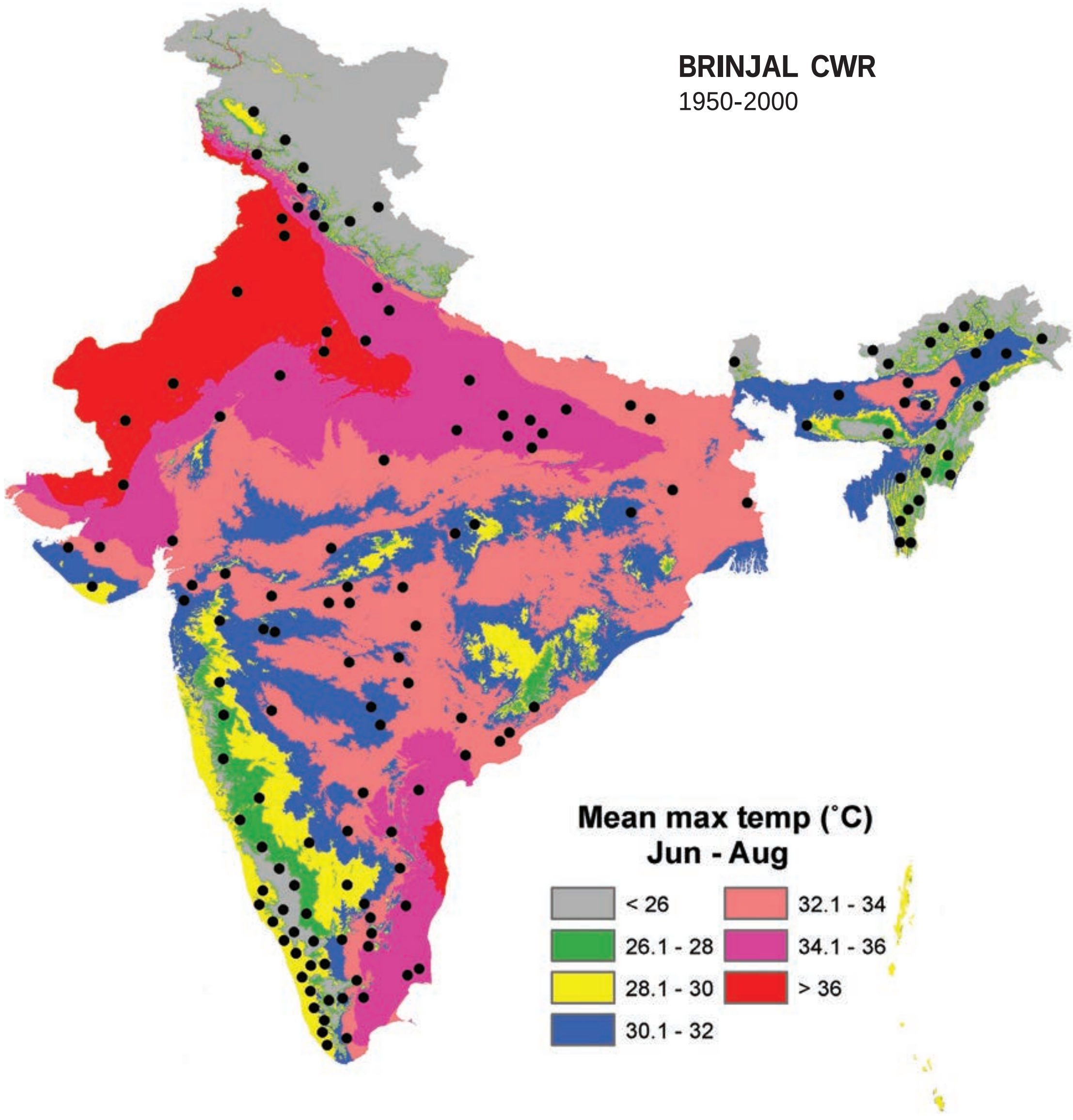


Figure 31: Quantitative changes in the areas under different temperature regimes for 1950-2000 overlaid with sites of collection for brinjal CWR for Jun-Aug season to identify vulnerable locations and areas with pre-adapted germplasm.

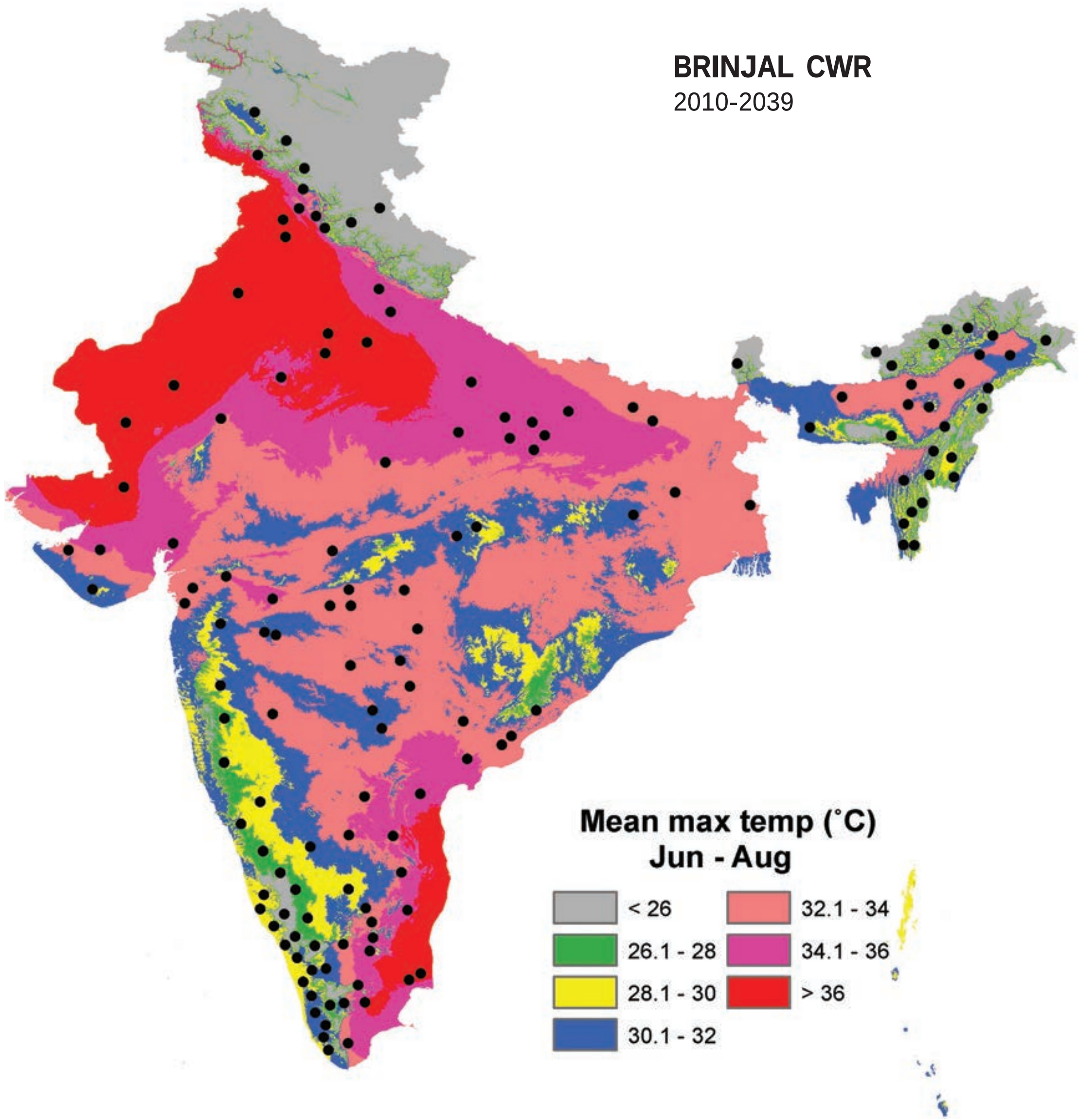


Figure 32: Quantitative changes in the areas under different temperature regimes predicted for 2010-2039 overlaid with sites of collection for brinjal CWR for Jun-Aug season to identify vulnerable locations and areas with pre-adapted germplasm.

5

Results: Identification of vulnerable areas and pre-adapted germplasm

Statistical clustering and climate matching in wheat, sorghum, pearl millet, pigeon pea and chickpea were carried out before identifying vulnerable locations. On the other hand, direct map-based deduction method was employed in rice, chilli pepper, brassica, brinjal and sesame.

The sites from where germplasm accessions have been collected gave an indication of the areas where diversity would be most likely to exist in these five crops. A drastic increase in the temperature would make the areas unsuitable for sustenance of the populations and they would become vulnerable. Based on the predictions of change in the mean monthly maximum temperatures in 2010-2039, areas which were predicted to be added to the top bracket (at or beyond higher end of the temperature range observed for the crop) temperature regimes were identified as potential vulnerable areas. The exact geographical locations of the predicted vulnerable areas were worked out for planning collection missions. Details are given crop-wise.

Germplasm accessions previously collected from sites that have been experiencing the top bracket of temperatures in the current climate (1950-2000) are expected to be subjected to natural selection pressure and were predicted to be best adapted to the local conditions. Such genotypes performing better (reflected by farmers' choice) would therefore be considered as pre-adapted to the natural as well as agronomic conditions. Such pre-adapted genetic material may be tested for their suitability to future vulnerable areas. To augment maximum adaptive alleles in each of the target crops and to plan further exploration missions, areas were identified and maps were generated.

Table 2. Details of pre-adapted germplasm based on current study.

SN	Crop name	No. of accession georeferenced	No. of preadapted accession
1	Wheat	9499	12
2	Rice	21654	875
3	Sorghum (*rabi*)	10947	34
4	Sorghum (*kharif*)		116
5	Pearl millet	8220	822
6	Chickpea	4236	82
7	Pigeon pea	6167	43
8	Oil seed brassica	3510	0
9	Sesamum CWR	348	99
10	Chilli pepper	4019	918
11	Brinjal CWR	408	12

Table 3. Details of vulnerable locations based on current study.

SN	Crop	No. vulnerable locations[1]	Vulnerable locations with collections[2]	No. of germplasm accessions from vulnerable locations
1	Bread Wheat	2039	34	261
2	Durum Wheat			197
3	Rice	912	21	899
4	Sorghum (*rabi*)	1174	42	2287
5	Sorghum (*kharif*)	541	42	116
6	Pearl millet	593	28	544
7	Chick pea	1445	33	204
8	Pigeon pea	728	28	238
9	Oil seed brassica	178	5	25
10	Sesame CWR	912	1	1
11	Chilli pepper	616	26	208
12	Brinjal CWR	563	5	11

[1]number of taluks predicted to experience top tier temperatures in 2010-2039
[2]number of taluks with accessions in the genebank
Taluk is the smallest administrative boundary in India.

WHEAT

In wheat, each temperature regime was predicted to shift to +2 °C regime. Areas in Punjab, Haryana and western UP (26-38 °C) would reduce by 6%. The largest swathe covered by 28-30 °C would reduce by 17%. Areas in 30-32 °C would increase by 5% and central and peninsular zones would experience mean maximum temperatures beyond 34 °C. The increase in areas under different temperature regimes (Figure 9 and 10) contrasts with the number of actual affected locations from where accessions were sourced. For instance, a large area change is predicted in temperature range 32-34 °C. However, greater effect of elevated temperatures on the germplasm occurring areas is observed in the range of 28-30°C. Together, climate maps and the Figure 33, help identify vulnerable areas (greater germplasm occurrence) and pre-adapted germplasm occurrence in extreme current temperatures (>32°C). It is also important to note that sites predicted to experience >32°C mean maximum temperature account for durum wheat.

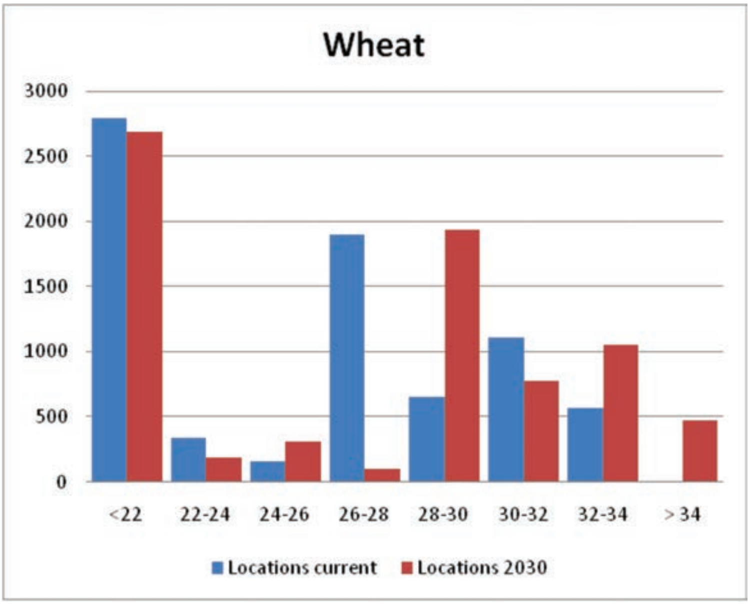


Figure 33: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of wheat season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of wheat germplasm occurrence.

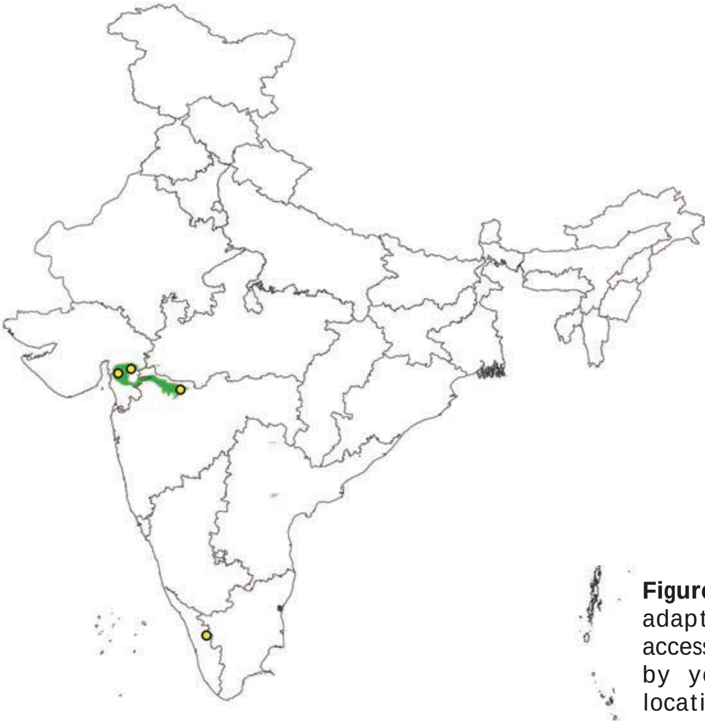


Figure 34: Predicted sites of sourcing pre-adapted wheat germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

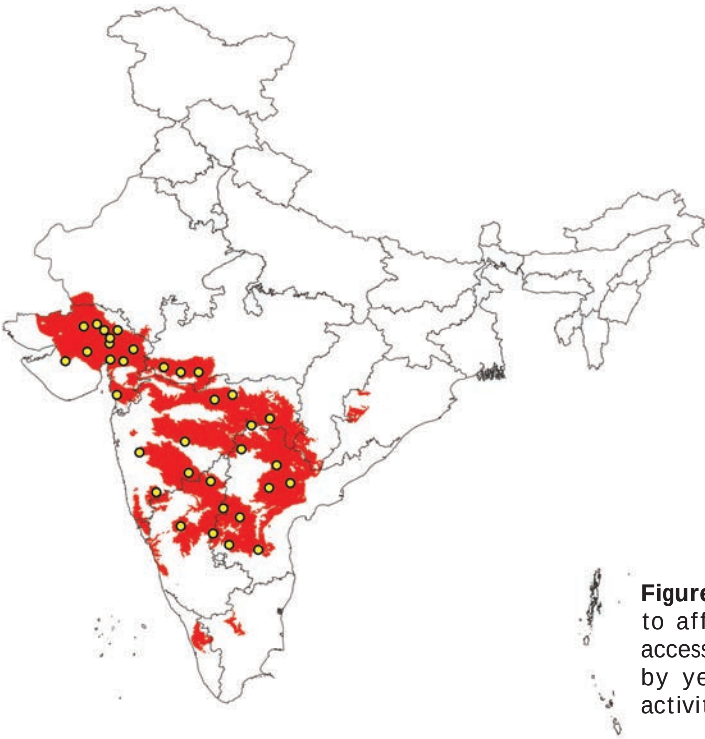


Figure 35: Vulnerable locations predicted to affect wheat germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

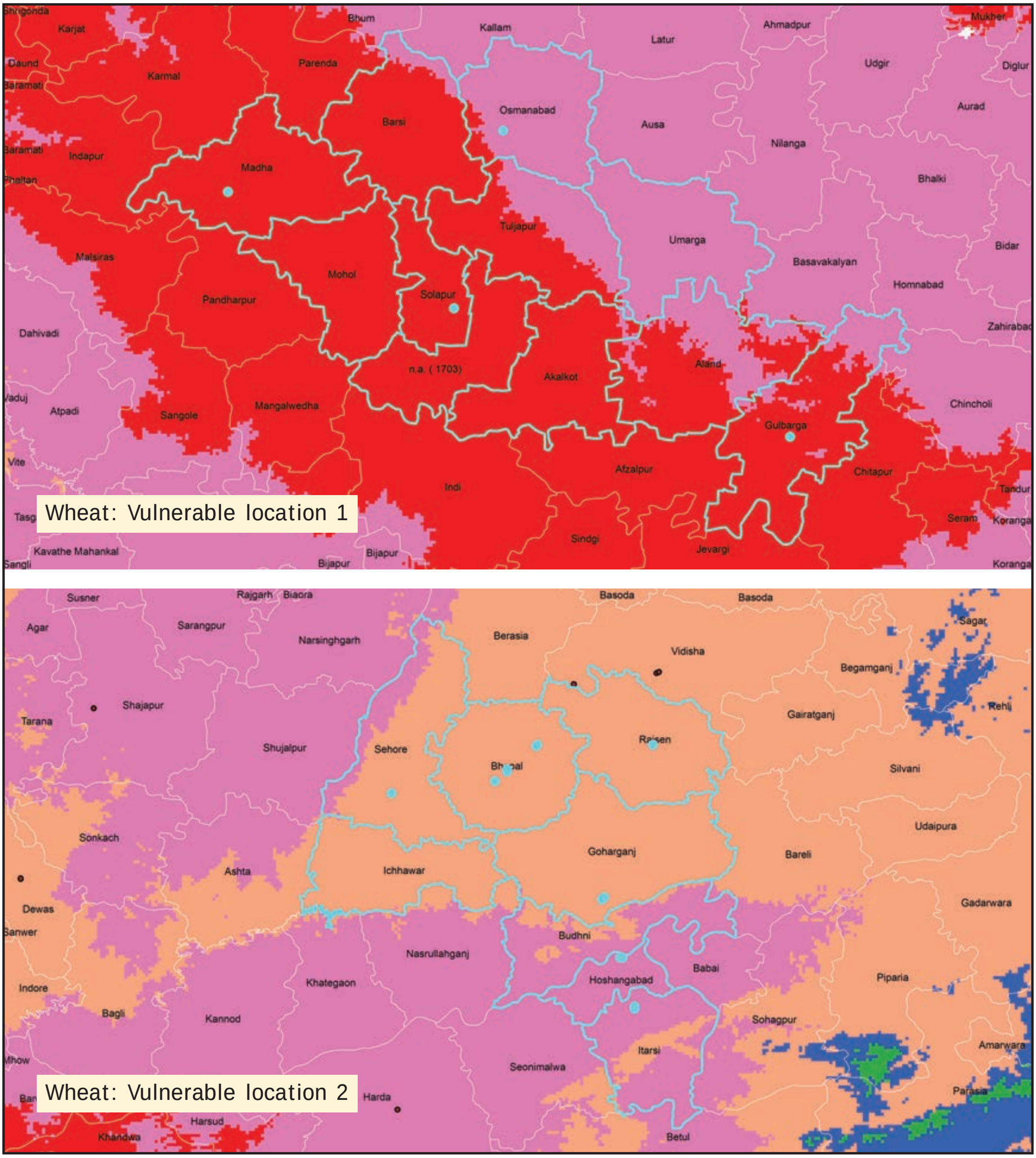


Figure 36: Two of the vulnerable sites identified in wheat. Vulnerable location1 comprising Afzalpur, Akalkot, Aland, Baramati, Barsi, Chitapur, Gulbarga, Indapur, Jevargi, Karjat, Karmal, Madha, Mangalwedha, Mohol, Pandharpur, Parenda, Sangole, Sedam, Sindagi, Solapur, Tandur, Tuljapur taluks in Karnataka, Maharashtra andTelangana states. Vulnerable location 2 comprising Basoda, Berasia, Bhopal, Budhni, Gairatganj, Goharganj, Hoshangabad, Ichhawar, Itarsi, Piparia, Raisen, Sagar, Sehore, sehore, Silvani, Udaipuraand Vidisha taluks in MP.

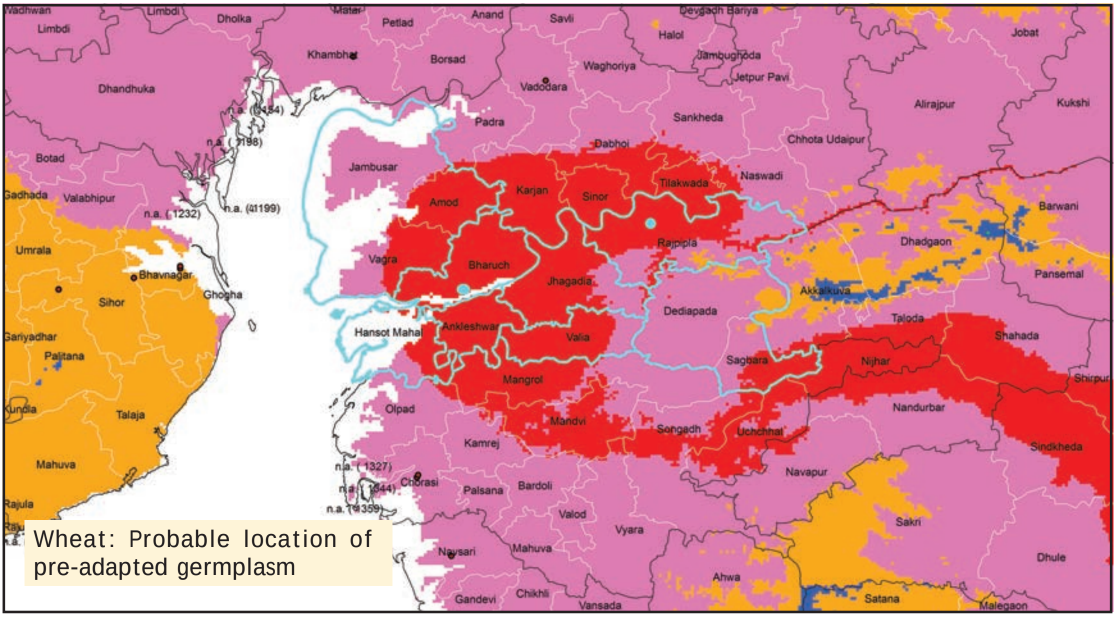


Figure 37: One of the sites of sourcing pre-adapted wheat germplasm, includesAnkleshwar, Bharuch, Jhagadia, Rajpipla, Tilakwada, Sinor, Karjan, Amod, Vagra, Valia,Mangrol, Mandavi, Songadh, Uchchhal, Nijhar and Sindkheda taluks. Genebank's accessions short-listed are CWI22746, PI 41342, IC 28689 and IC 336999.

The climate maps and predictions in case of wheat point to the fact that majority of the vulnerable locations would be found in peninsular India. However, it is important to note that a number of these locations are known for durum wheat. Further, the major wheat growing areas such as indo-gangetic plains do not host landraces anymore. It is therefore important not to draw conclusions from the pan-India predictions depicted in this report. Smaller areas tend to throw better predictions and allow PGR workers to practically implement the collection programmes. In one such area specific analysis, we identified a small pocket in Madhya Pradesh and carried out germplasm collection (see page 84).

RICE

Rice, a native of India, is cultivated across a wide range of latitudes, altitudes, day-lengths, and growing seasons in different agro-ecological zones. PGR work focuses on the great number of landraces and locally adapted genotypes grown in small pieces of land in traditional rice growing areas. It is in these ecologies that climate change effect, if any, would be manifested in the form of decline in genetic diversity. In rice, it has been shown that there would be a decline in rice yield by 6% for every one degree rise in temperature[3]. Analyses of pan-India data on rice is difficult and yields erroneous conclusions. From lower latitude of southern coast and sub-coastal regions to Chhattisgarh and Odisha to North-East states season and crop-duration differ significantly. Any predictions, based on the average temperatures, for Kerala will be dissimilar to the ones for Assam. Two sets of predictions are presented that illustrate the drastic differences (**Figures 11-14**). The differences only highlight the need for an approach limited to individual niches. Germplasm sites affected by predicted increase in temperature (**Figure 38**) needs to be calibrated based on the disparate observations.

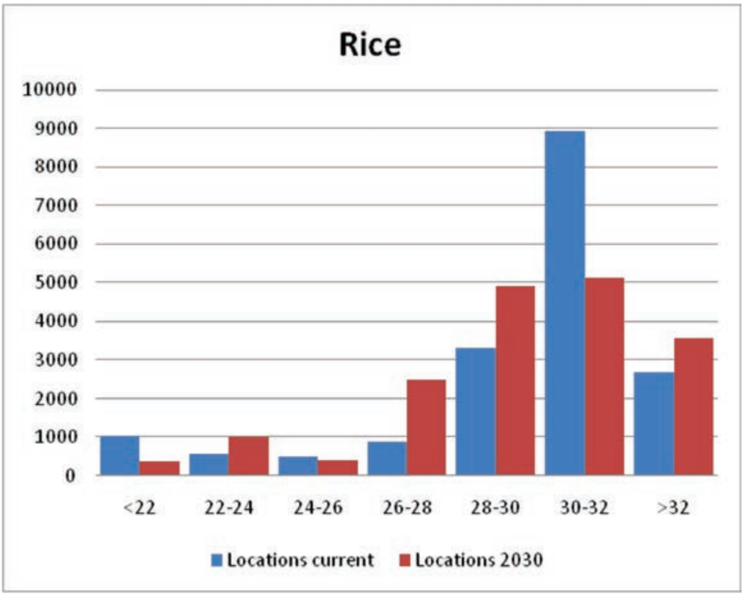


Figure 38: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of rice season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of wheat germplasm occurrence.

[3] Saseendran et al. (2000). Effects of Climate Change on Rice Production in the Tropical Humid Climate of Kerala, India Climatic Change 44: 495-514.

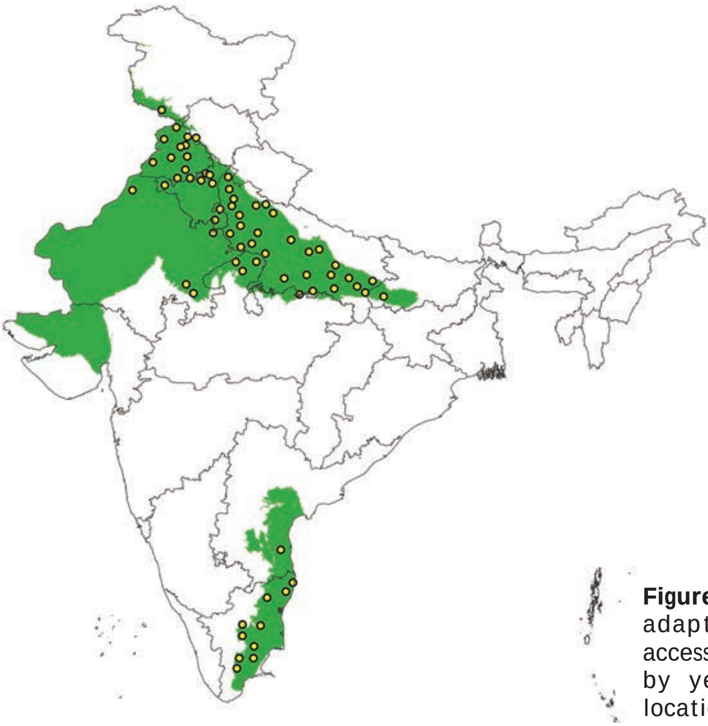


Figure 39: Predicted sites of sourcing pre-adapted rice germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

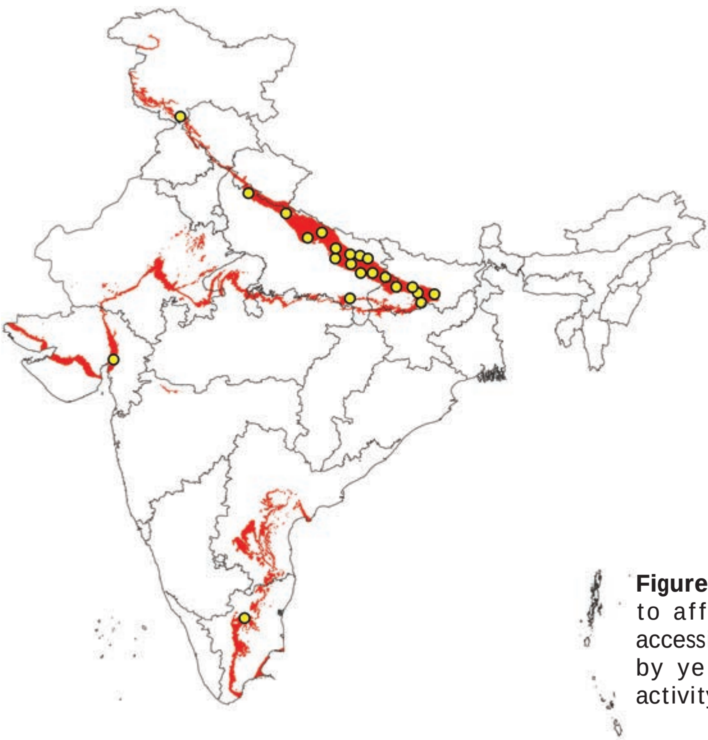


Figure 40: Vulnerable locations predicted to affect rice germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

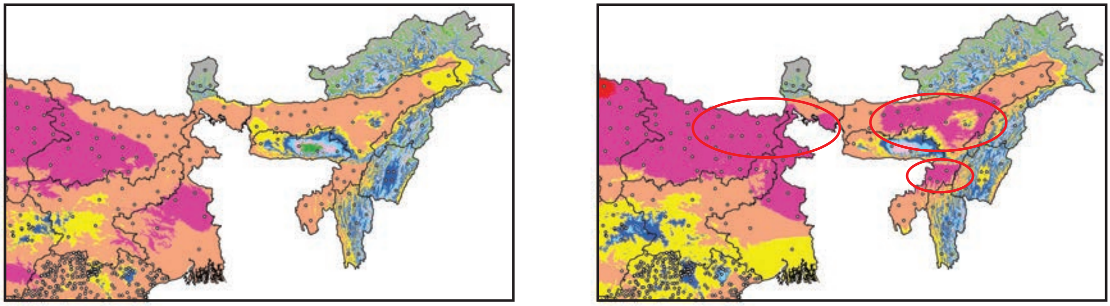


Figure 41: Vulnerable locations predicted to affect rice germplasm in North-east India.

Northen West-Bengal and eastern Bihar are predicted to experince 2ºC rise. This area houses several unique and endemic rice landraces. Germplasm collection activities need to be intensified before landraces are dwindled.

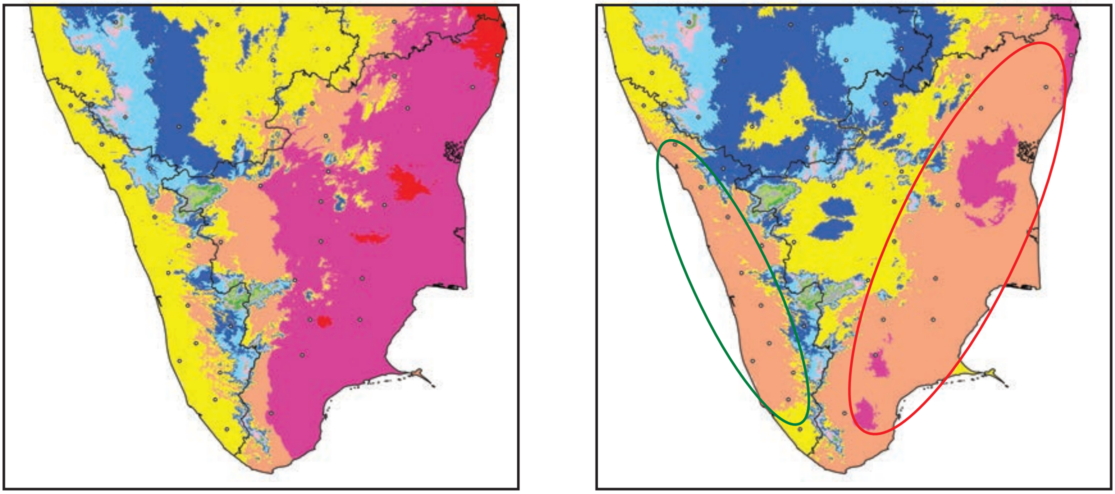


Figure 42: Locations predicted to affect rice in southern India.

Two different scenarios can be noticed along eastern and western sub-coastal regions. Marked areas are predicted to experience 2ºC rise in temperature. While there is an increase of 2ºC in along western subcoastal region, temperature is predicted to come down by 2ºC in eastern subcoastal region.

PEARL MILLET

The seasonal climatic predictions in pearl millet showed minor charges of 4% shift from 32-34 °C to >34 °C in overall area affected. However, locations from where pearl millet germplasm have been collected [sites where pearl millet germplasm are found] were predicted to be affected significantly [figure 43]. Sites were shown to shift from 32-34°c mean maximum temperature to the next level of > 34°c.

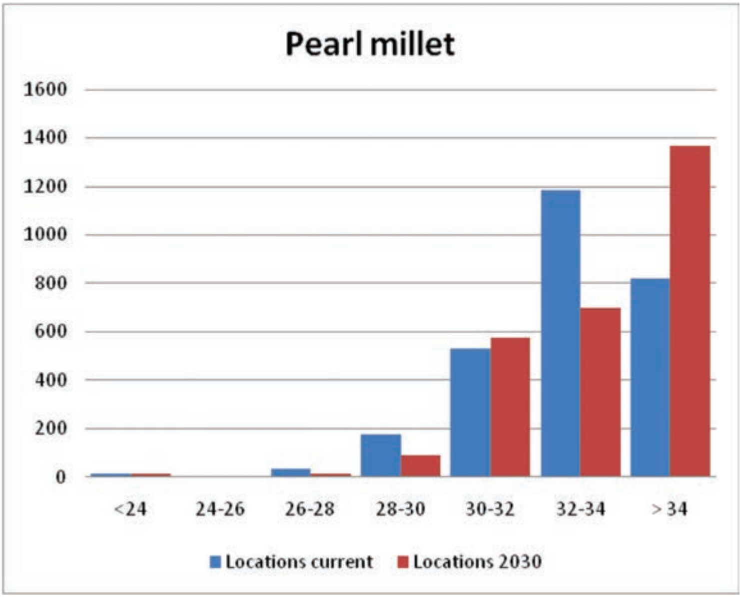


Figure 43: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of pearl millet season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of pearl millet germplasm occurrence.

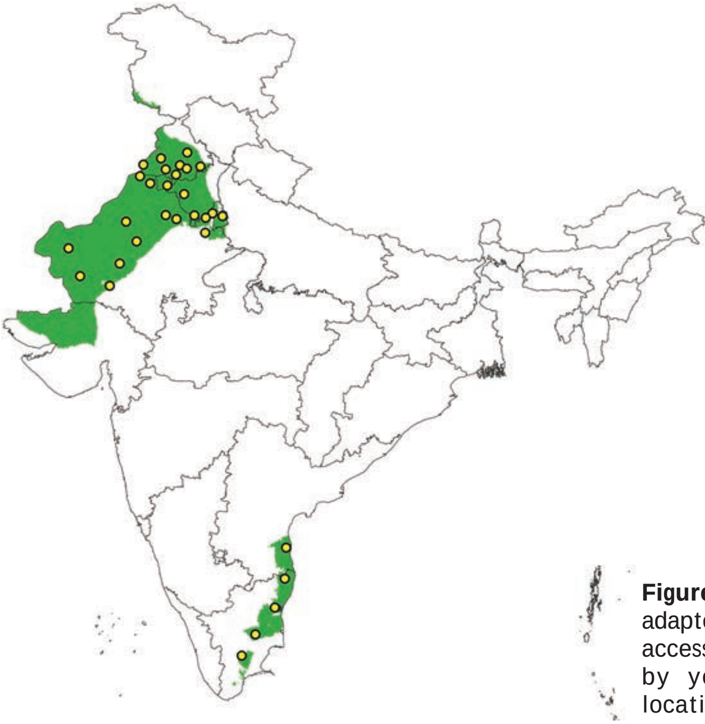


Figure 44: Predicted sites of sourcing pre-adapted pearl millet germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

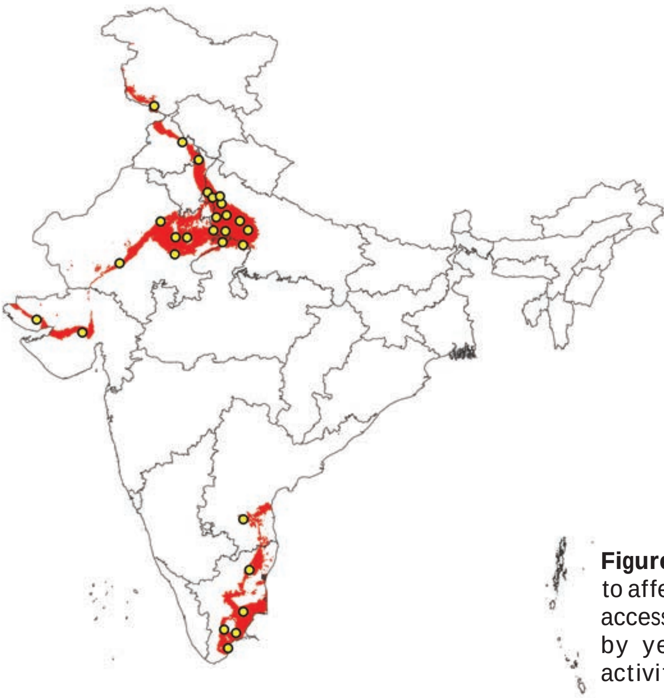


Figure 45: Vulnerable locations predicted to affect pearl millet germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

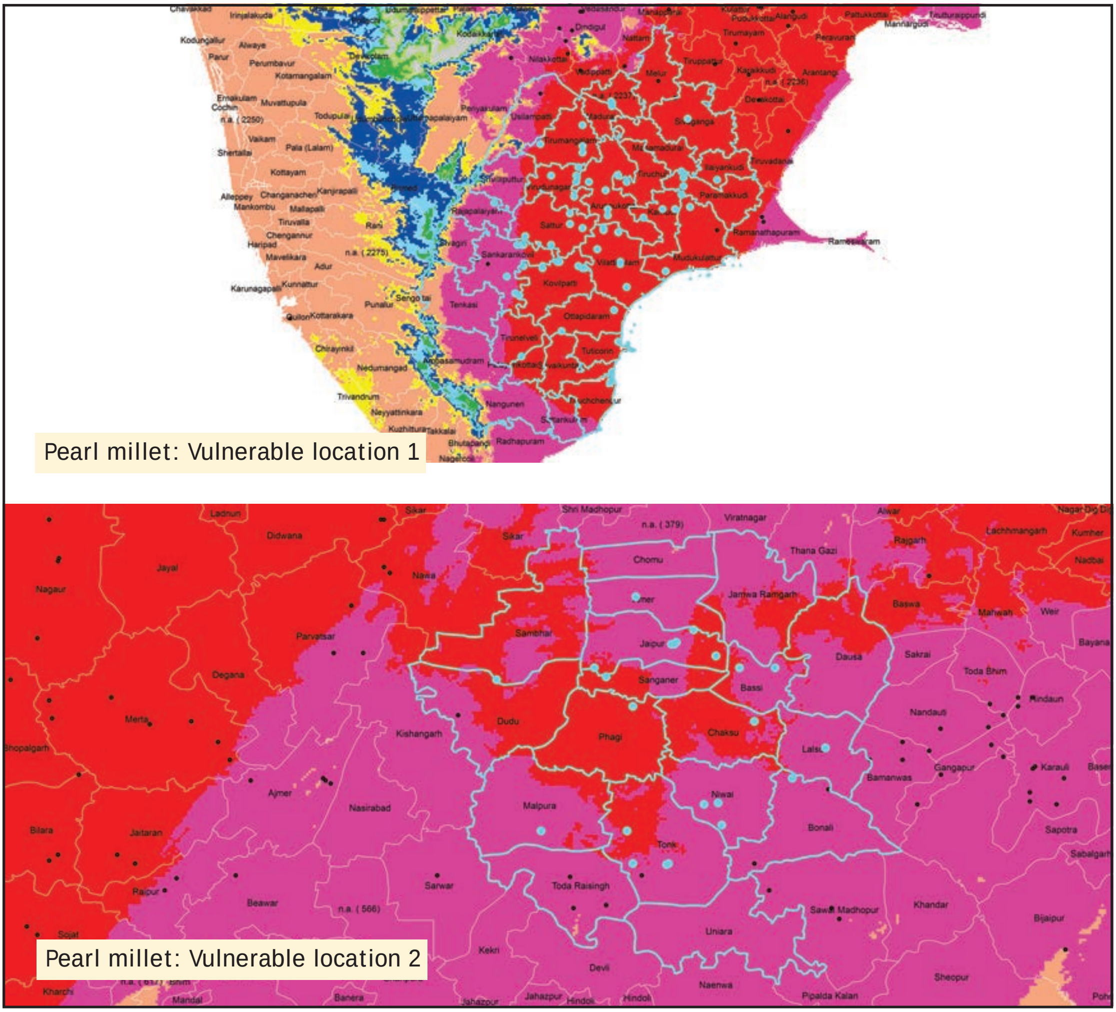


Figure 46: Two of the vulnerable sites identified in pearl millet. Also given are the names of taluks from where collection activities are to be planned. Aruppukottai, Ilaiyankudi, Kamudi, Kovilpatti, Madurai, Manamadurai, Melur, Mudukulattur, Ottapidaram, Palayankottai, Paramakkudi, Sattur, Sivaganga, Srivaikuntam, Tiruchchendur, Tiruchuli, Tirumangalam, Tirunelveli, Tuticorin,Vilattikulam and Virudunagar taluks in the vulnerable location 1. Alwar, Baswa, Chaksu, Dausa, Dudu, Jamwa Ramgarh, Nawa, Phagi, Rajgarh, Sambhar, Sanganer, Sikar and Tonk taluks in the vulnerable location 2.

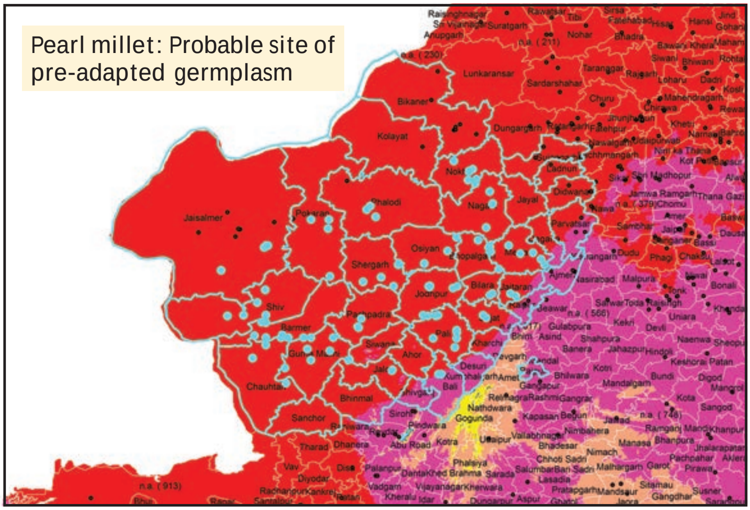


Figure 47: Sites of sourcing pre-adapted pearl millet germplasm. Accessions short-listed are given in the table below.

Accession	Cluster	Accession	Cluster	Accession	Cluster
3221	12	3158	15	3204	16
3220	12	3156	15	20140	16
3216	12	3426	15	20125	16
370718	12	3160	15	20123	16
3422	13	3161	15	3192	16
20085	13	3230	15	3188	16
3425	13	20082	15	3189	16
20150	15	80714	15	3191	16
20151	15	20161	15	3175	16
20130	15	3162	15	20110	16
20131	15	20156	15	3173	16
3224	15	1011	15	11889	16
1034	15	3432	15	3171	16
3225	15	3234	15	3170	16
3207	15	3445	15	3245	16
80036	15	20134	15	80950	16
3226	15	3213	15	3251	16
1512	15	20147	15	1013	16
20136	15	20141	15	3256	16
3212	15	80630	15	1026	16
20137	15	3199	15	3262	16
8306	15	1071	15	3260	16
1035	15	3210	15	1015	16
1036	15	20162	15	20129	16
3154	15	1466	15		
3157	15	3203	16		

SORGHUM

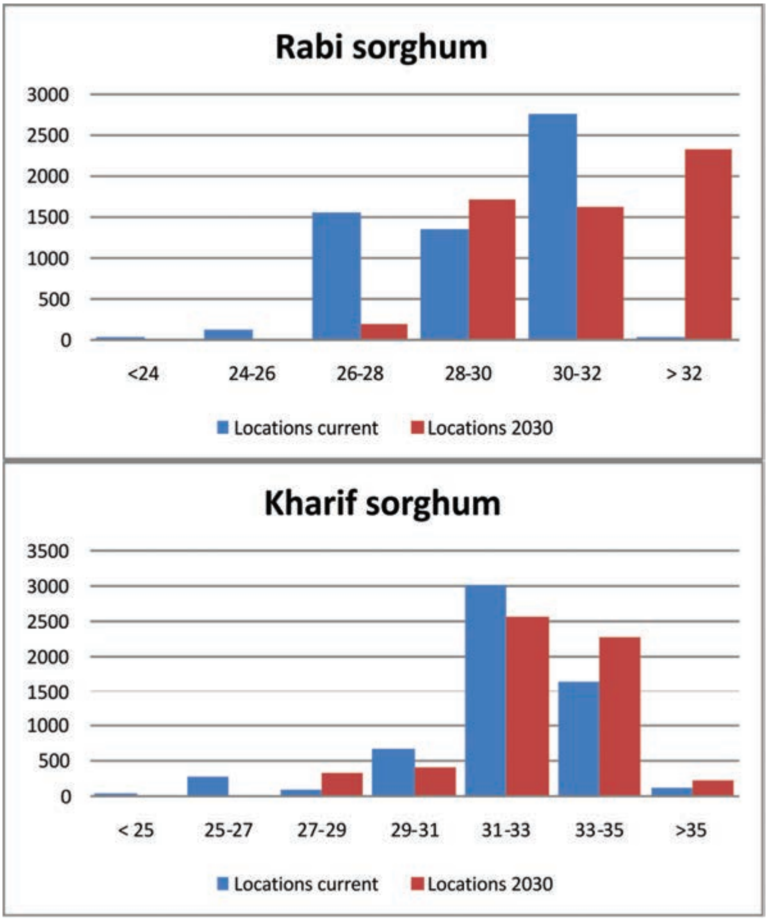


Figure 48: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of sorghum season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of sorghum germplasm occurrence.

It was not possible to differentiate the germplasm collection data of sorghum between those carried out in *kharif* and *rabi* seasons. Predictions and analyses for both the seasons were carried out employing entire sorghum data. The results showed distinct patterns of changes [Figure 48]. Sorghum researchers need to bank on the ground data on germplasm occurrence to draw specific conclusions.

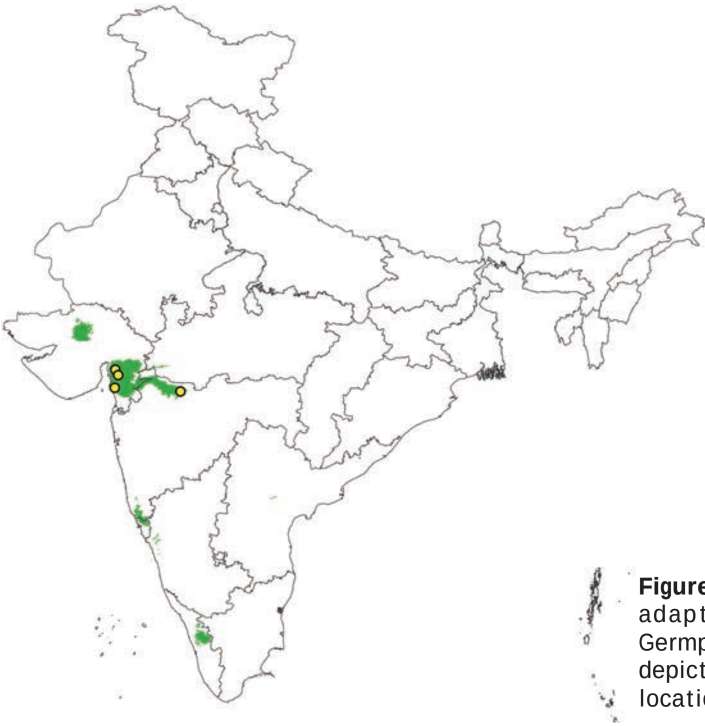


Figure 49: Predicted sites of sourcing pre-adapted *rabi* sorghum germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

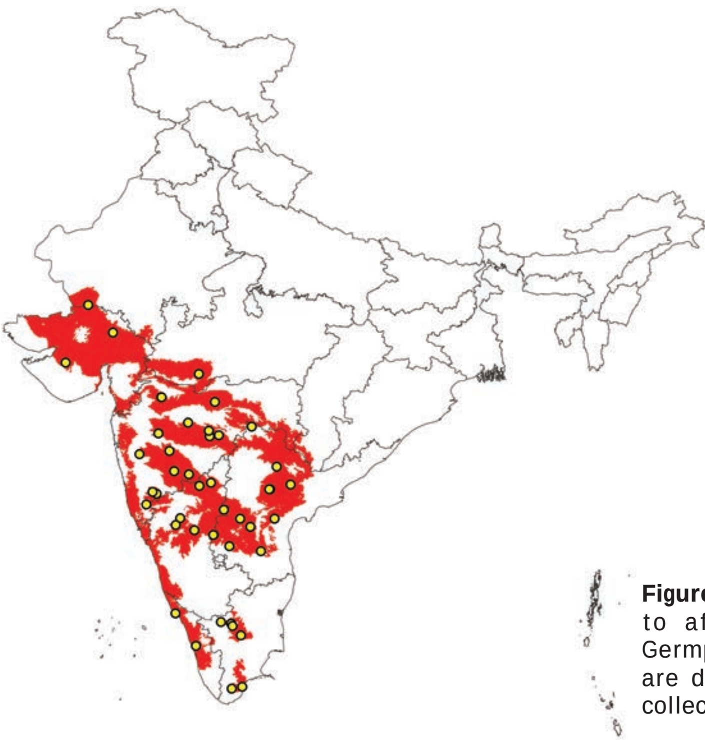


Figure 50: Vulnerable locations predicted to affect *rabi* sorghum germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

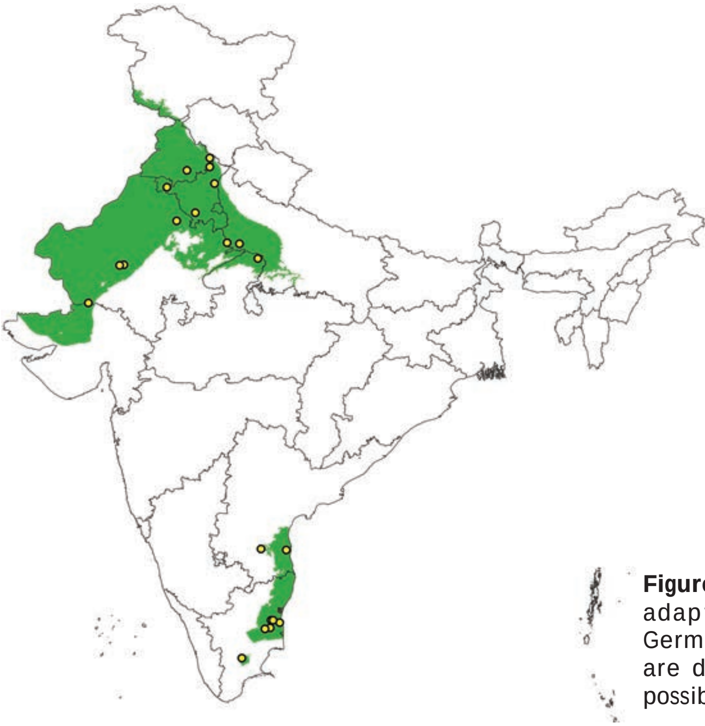


Figure 51: Predicted sites of sourcing pre-adapted *kharif* sorghum germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

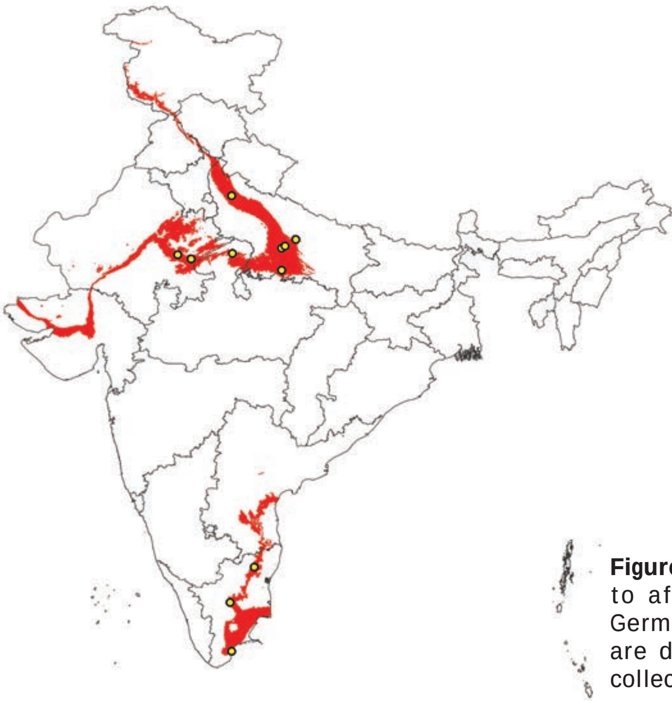


Figure 52: Vulnerable locations predicted to affect *kharif* sorghum germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

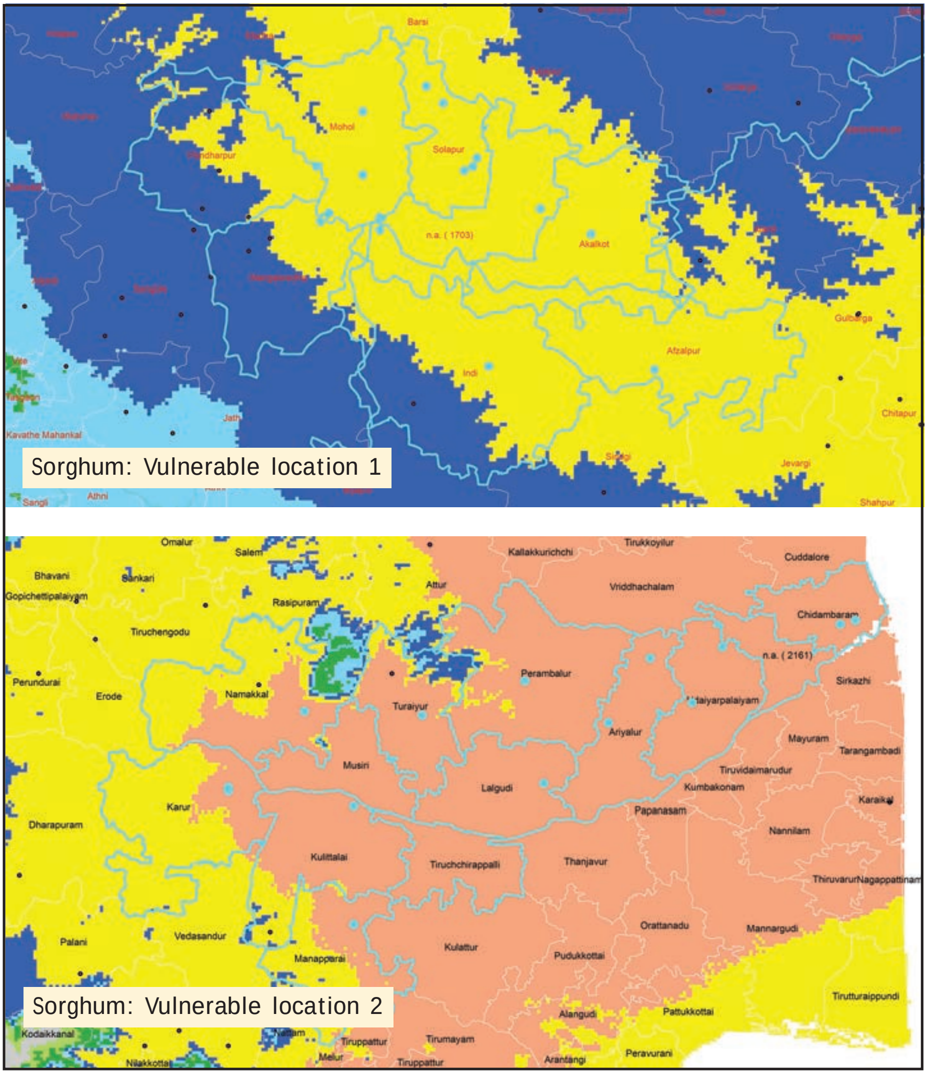


Figure 53: Two of the vulnerable sites identified in sorghum. Afzalpur, Akalkot, Indi, Mangalwedha, Mohol, Pandharpur, Solapur taluks in the vulnerable location 1 and Ariyalur, Chidambaram, Karur, Kulittalai, Lalgudi, Manapparai, Musiri, Namakkal, Perambalur, Tiruchchirappalli, Turaiyur and Udaiyarpalaiyam taluks in the vulnerable location 2.

In rabi sorghum, areas have are predicted to shift from 26-30 °C to 28-32 °C and beyond causing a decrease of 18% in 26-28 °C and a simultaneous increase of 14% in the areas beyond 32 °C. In kharif sorghum, minor shifts of 2-4% were observed and the trend was an overall shift to temperatures beyond 31-33 °C.

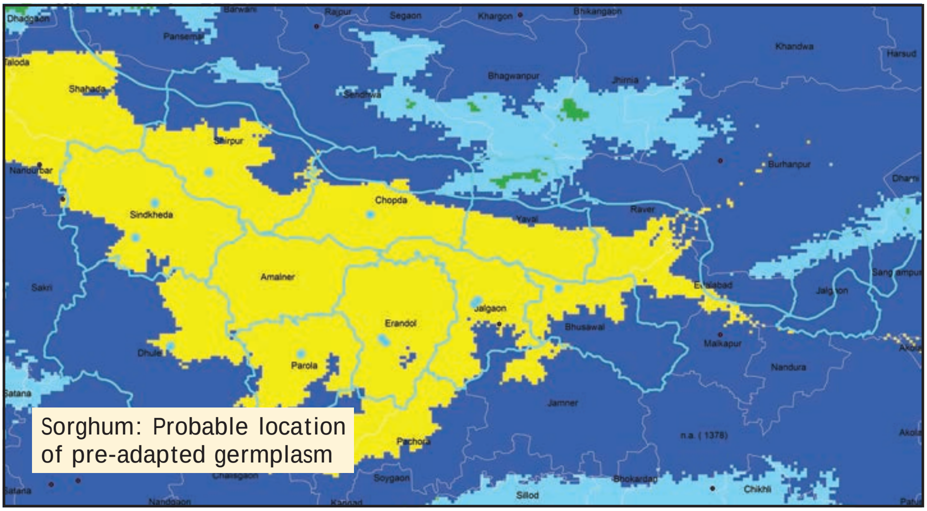


Figure 54: Site of sourcing pre-adapted sorghum germplasm. Accessions shortlistedare given in the table below.

Accession	Cluster
24346	16
40725	16
24341	16
40688	16
21997	16
290510	16
4542	16
40674	16
24348	16
40703	16
40692	16
40697	16

CHICKPEA

Predictions for the chickpea showed that In chickpea, 35% of the area was in 27-29 °C and in future it was found to change to 33% area in 29-31 °C regime and area in the extreme temperature of >31 °C was found to increase to 24% from 6%. These observations made on the total area changes hold true even for the sites from where chickpea germplasm were collected [Figure 55]. It was predicted that locations experiencing mean maximum temperature beyond 29°c would increase in near future affecting the occurrence and composition of chickpea germplasm.

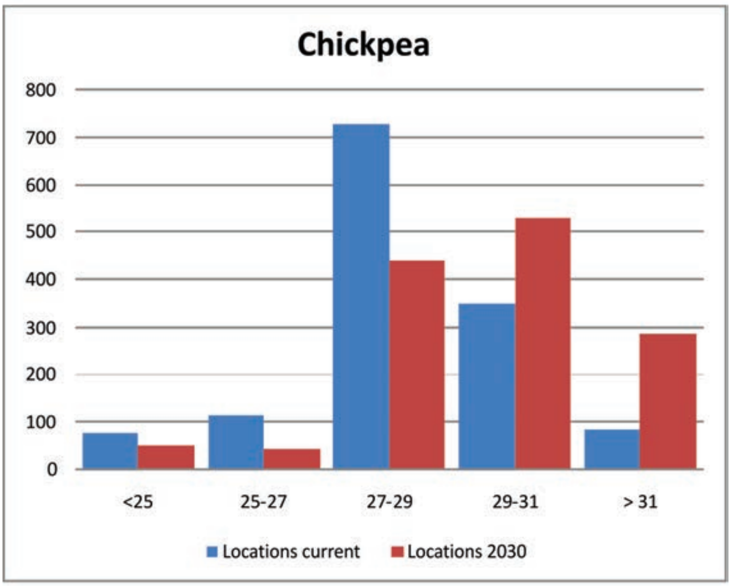


Figure 55: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of chickpea season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of chickpea germplasm occurrence.

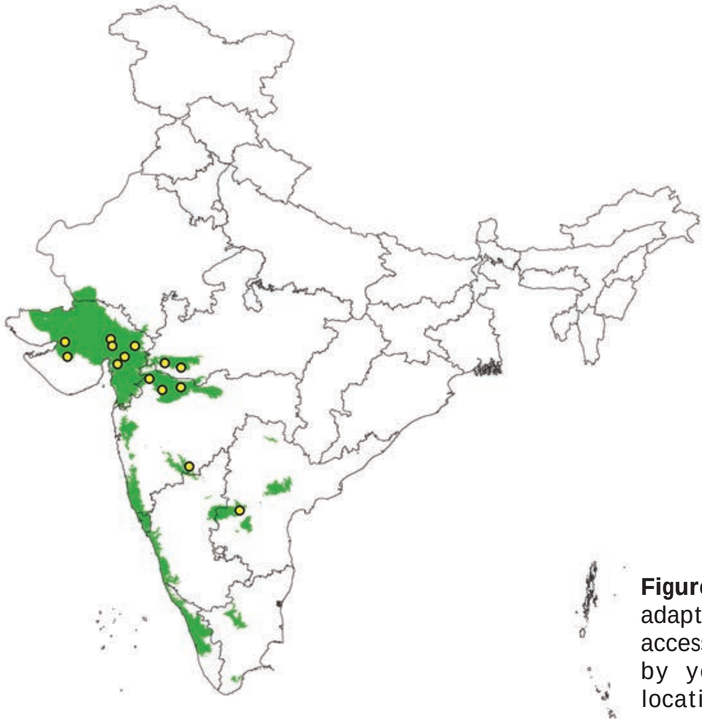


Figure 56: Predicted sites of sourcing pre-adapted chickpea germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

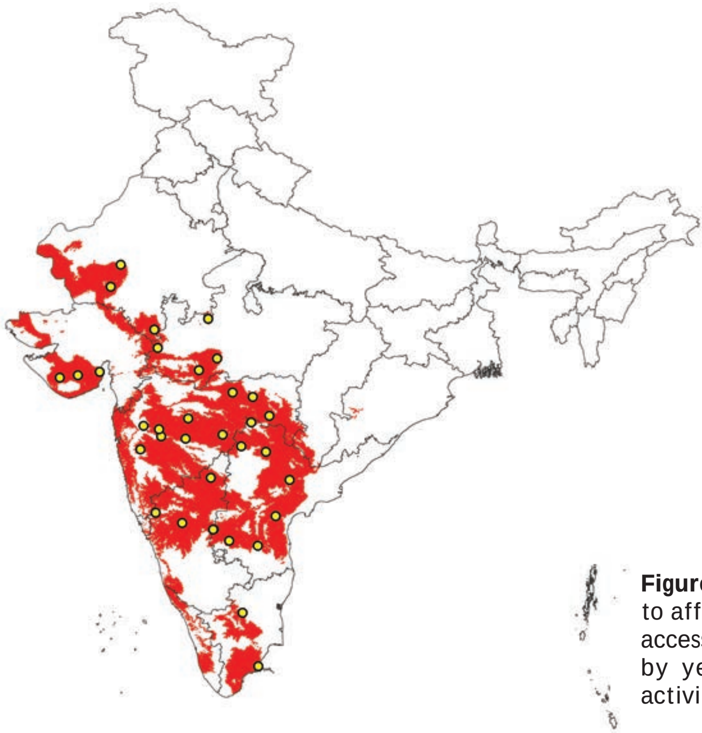


Figure 57: Vulnerable locations predicted to affect chickpea germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

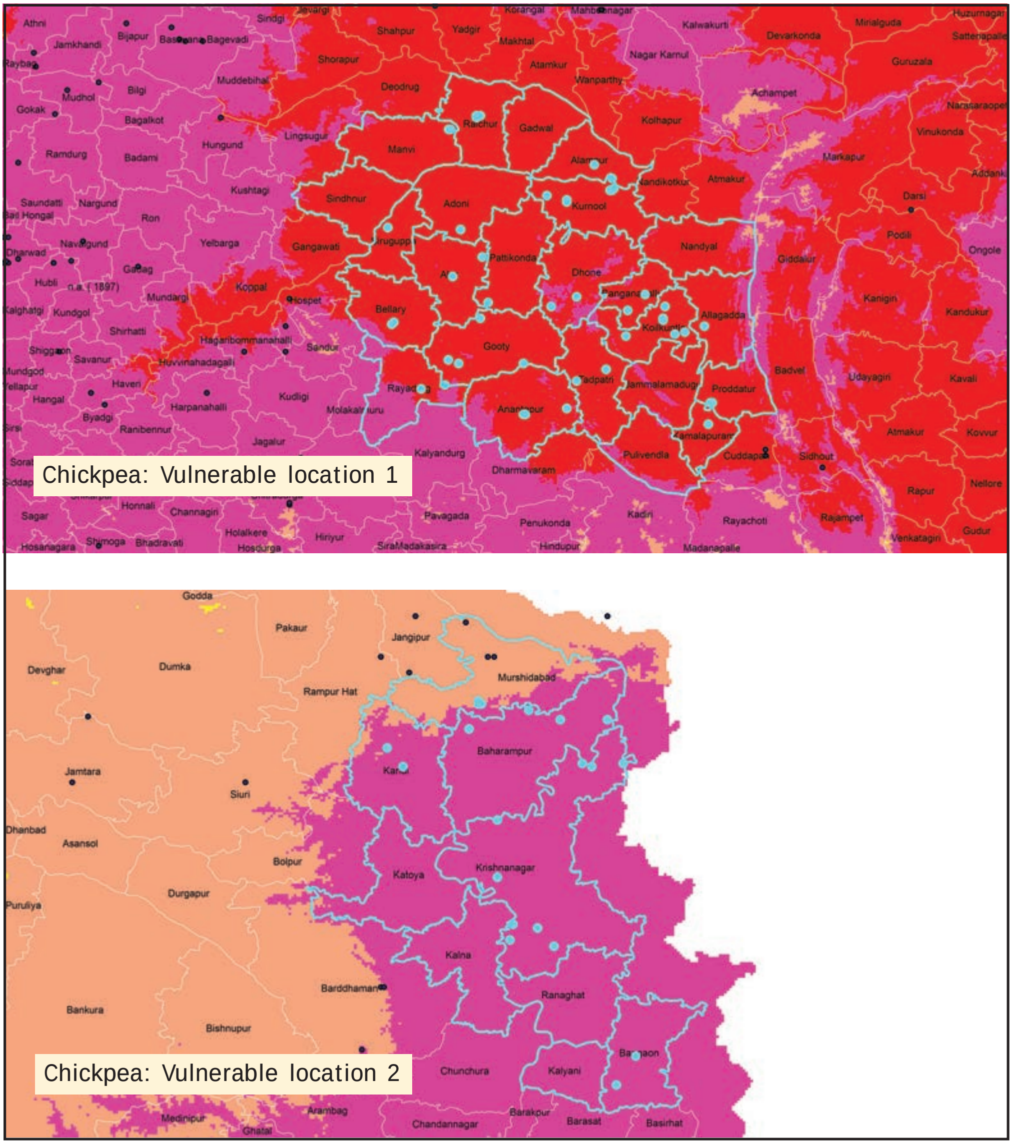


Figure 58: Two of the vulnerable sites identified in chickpea. Names of taluks from where collection activities can be planned include Adoni, Alampur, Allagadda, Alur, Anantapur, Banganapalli, Bellary, Dhone, Gadwal, Gangavati, Gooty, Gulbarga, Jammalamadugu, Jevargi, Kadapa, Kamalapuram Koilkuntla, Koppal, Kurnool, Makhtal, Manvi, Nandyal, Pattikonda, Proddatur, Pulivendla, Raichur, Rayadurg, Shorapur, Sindhnur, Siruguppa, Tadpatri and Yadgir in vulnerable location 1 and Baharampur, Bangaon, Barasat, Basirhat, Chandanagar, Chunchura, Kalna, Kalyani, Kandi, Katoya, Krishnanagar, Murshidabad and Ranaghat in vulnerable location 2.

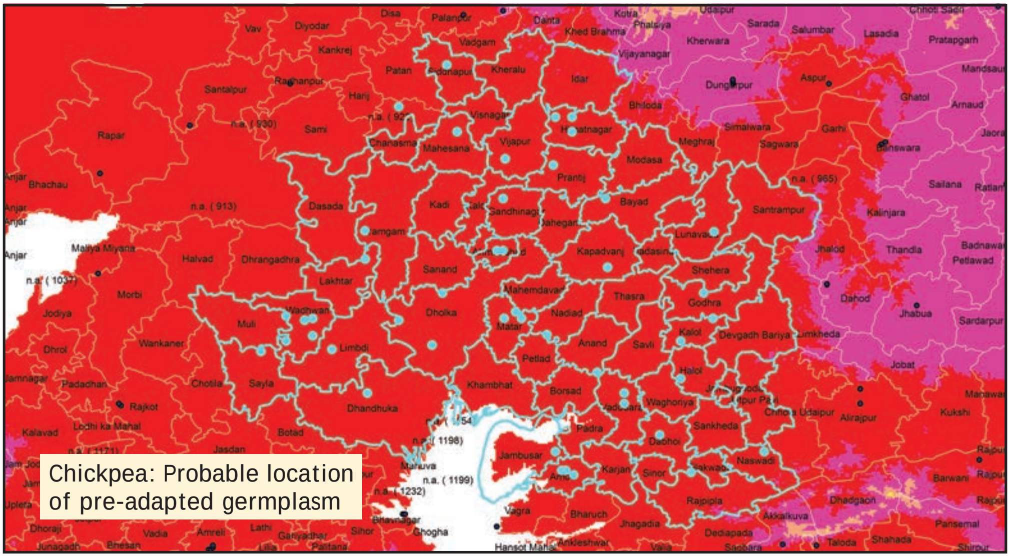


Figure 59: Sites of sourcing pre-adapted chickpea germplasm. Accessions short-listed are given in the table below.

Accession	Cluster	Accession	Cluster
SM11016	15	SM10992	16
SM11020	15	SM11191	16
SM11011	15	IC527926	16
SM10976	16	SM11024	16
IC270245	16	IG8250	16
SM11050	16	SM15679	16
SM11047	16	SM11018	16
SM11048	16	SM11192	16
SM10977	16	SM11000	16
IC395719	16	SM11015	16
SM15682	16	SM15004	16
SM11021	16	SM11049	16
SM15048	16	SM10983	16
SM10988	16	SM10991	16
SM10982	16	SM10999	16
SM10997	16	IC103797	16
SM10987	16	SM11026	16
SM11043	16	SM10993	16
SM11054	16	SM11045	17
SM10995	16	SM10998	16
SM10981	16	SM11028	16
SM10989	16	SM11022	16
SM11173	16		

PIGEON PEA

In pigeon pea, 41% of the area was predicted to change from 29-31 °C to 31-33 °C regime in future and area in the extreme temperature of >33 °C was found to increase to 14% from 5%. Although pigeon pea as a crop is known for heat tolerance and the changes seen in the germplasm sites [Figure 60] would not have serious effects on survival of genotypes, predicted changes in pest population due to elevated temperatures, would be expected to cause genetic changes.

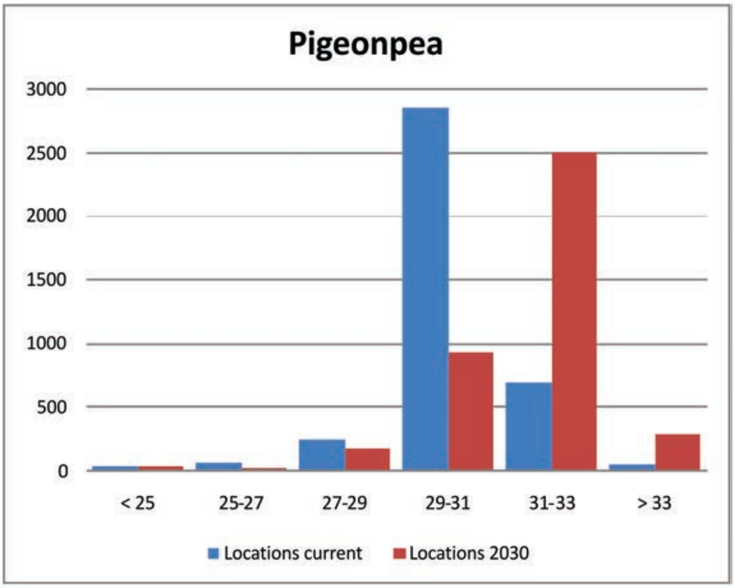


Figure 60: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of pigeon pea season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of pigeonpea germplasm occurrence.

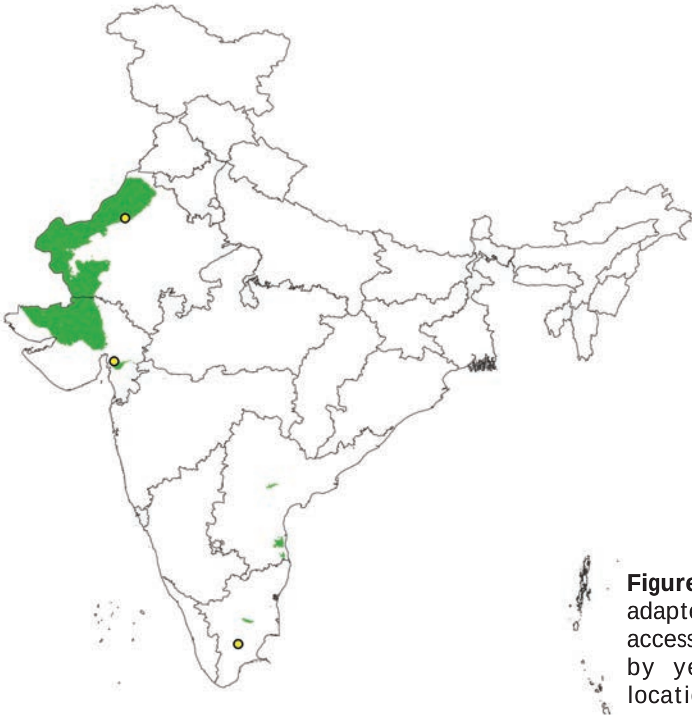


Figure 61: Predicted sites of sourcing pre-adapted pigeon pea germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

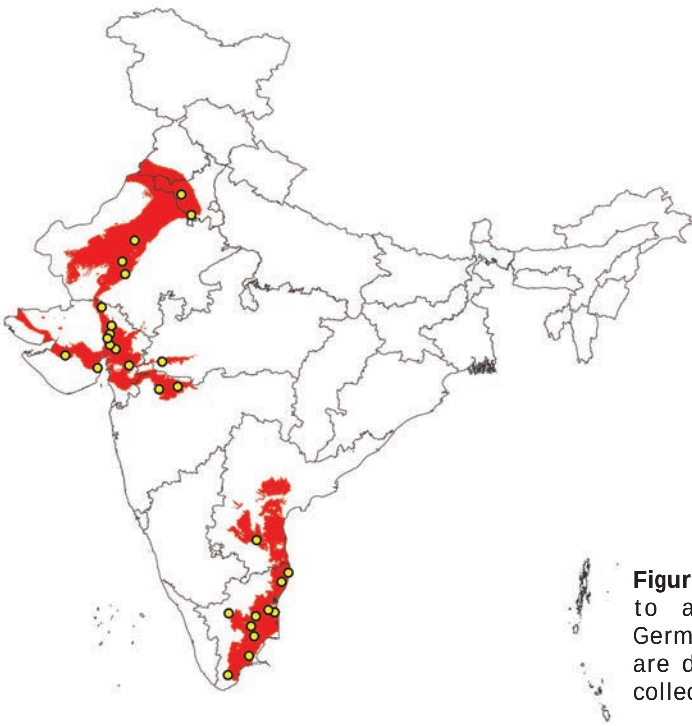


Figure 62: Vulnerable locations predicted to affect pigeon pea germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

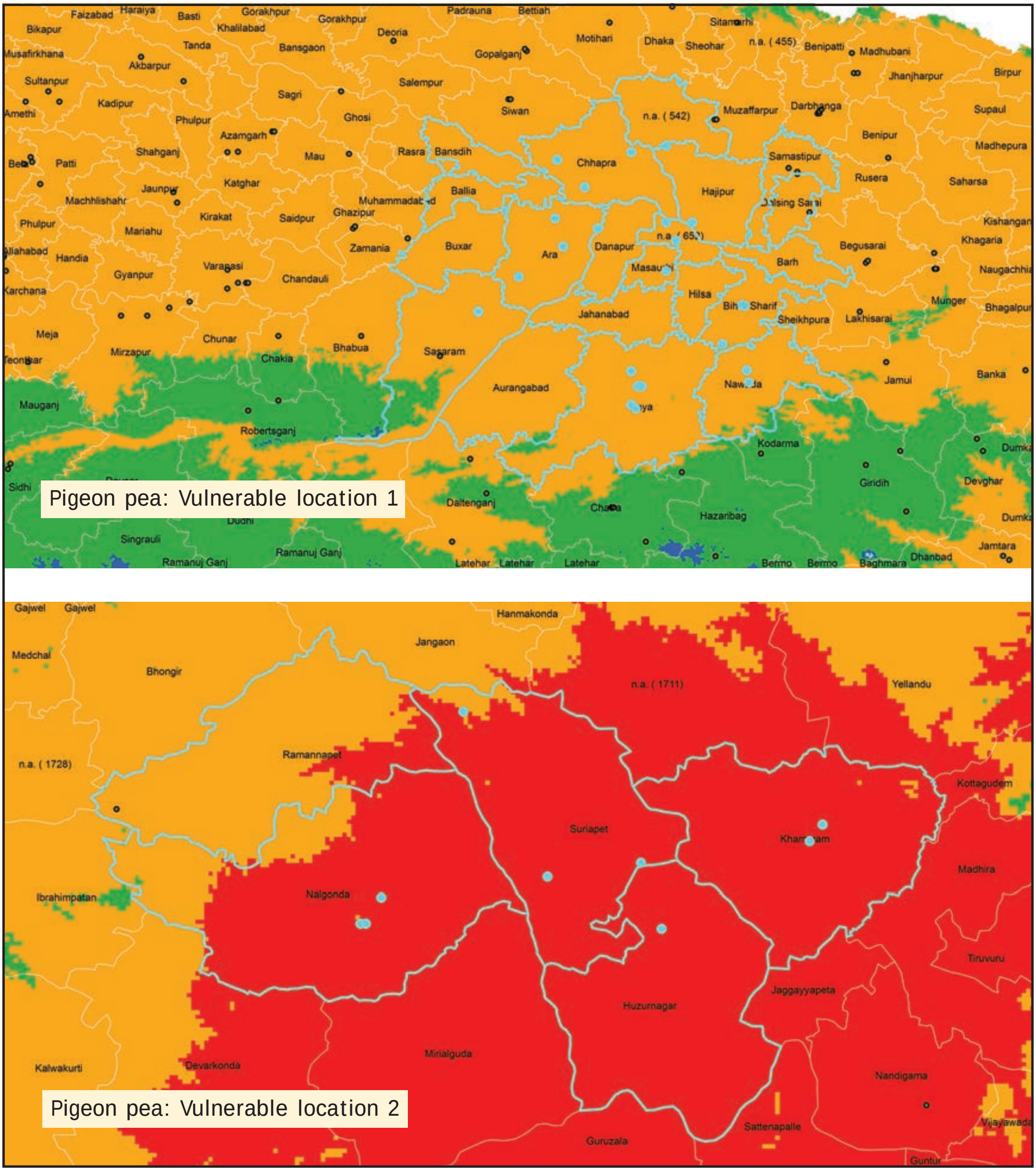


Figure 63: Two of the vulnerable sites identified in pigeon pea. Names of taluks from where collection activities canbe planned include Ara, Aurangabad, Ballia, Bansdih, Barh, Bihar Sharif, Buxar, Chhapra, Dalsing Sarai, Danapur, Gaya, Hajipur, Hilsa, Jahanabad, Masaurhi, Nawada, Samastipur and Sasaram in vulnerable location 1 and Huzurnagar, Khammam, Nalgonda, Ramannapet and Suriapet in vulnerable location 2.

OILSEED BRASSICA

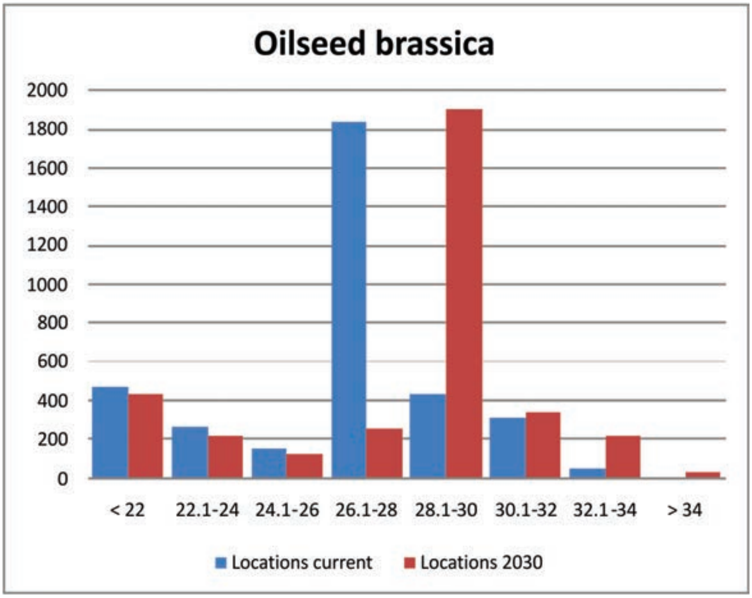


Figure 64: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of oilseed brassica season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of oilseed brassica germplasm occurrence.

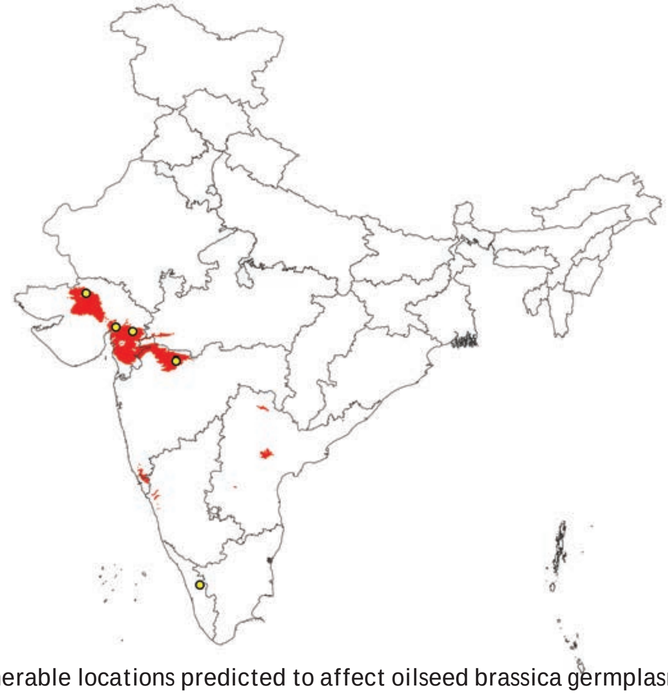


Figure 65: Vulnerable locations predicted to affect oilseed brassica germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

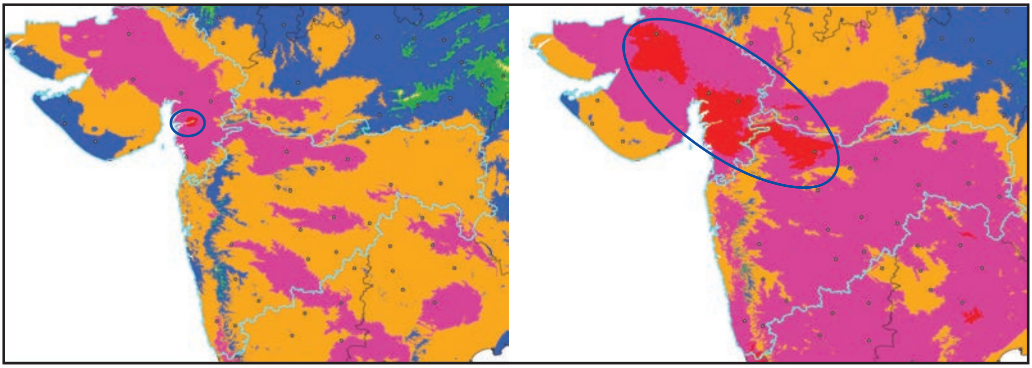


Figure 66: Temperature above 32 ºC is predicted to increase by a big margin in many areas. However, some sites of Gujarat and Maharastra-Gujarat border that experience temperatures beyond >34 ºC are predicted to expand drastically.

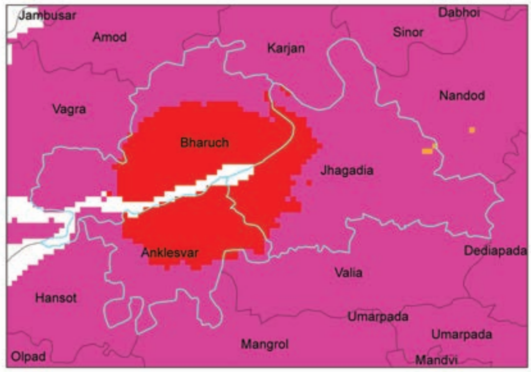


Figure 67: Pre-adapted germplasm are likely to occur in areas of Bharuch, Jhagadia and Ankleshwar in Bharuch District of Gujarat.

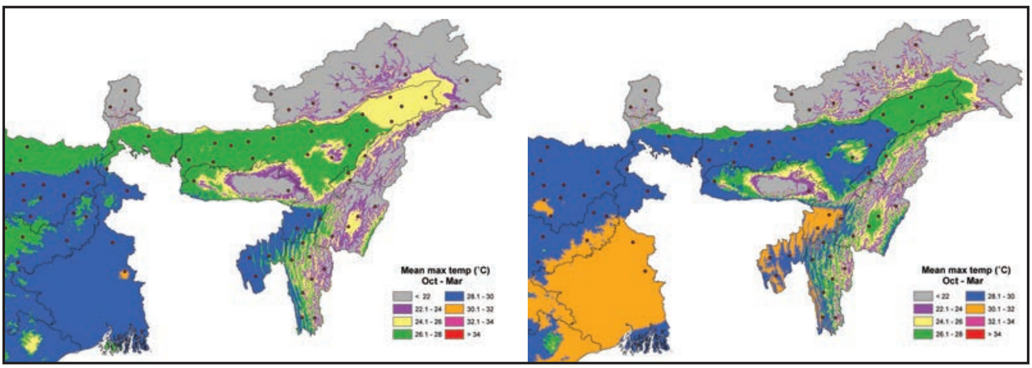


Figure 68: In Bihar, Bengal and the entire north east region, a 2 ºC upward shift is predicted in the mean maximum temperature. Many sites with rich diversity are expected to go vulnerable. The region also has sites where pre-adapted germplasm may be available viz. Nabadwip and Krishnanagar in Nadia district West Bengal.

SESAME CWR

Based on predictions for 2030, *Sesamum* CWR area in Kerala as well as NE region under temperature range 30-32 is expected to become hot with 32-34 ºC mean maximum temperature (**Figure 64**). Locally adapted genotypes of the species occurring in temperature bracket 30-32 ºC need to be collected lest they are lost. On the other hand, *Sesamum* CWR occurring in areas experiencing current temperatures beyond 34 ºC, do not appear to be in danger (**Figure 64**) as these areas are well known for sesame cultivation in remarkably hot season.

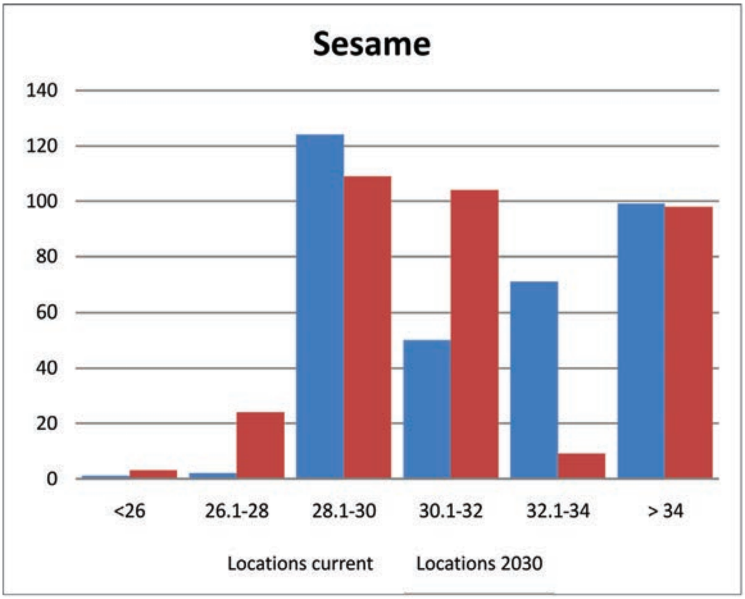


Figure 69: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of sesame CWR season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of sesame CWR germplasm occurrence.

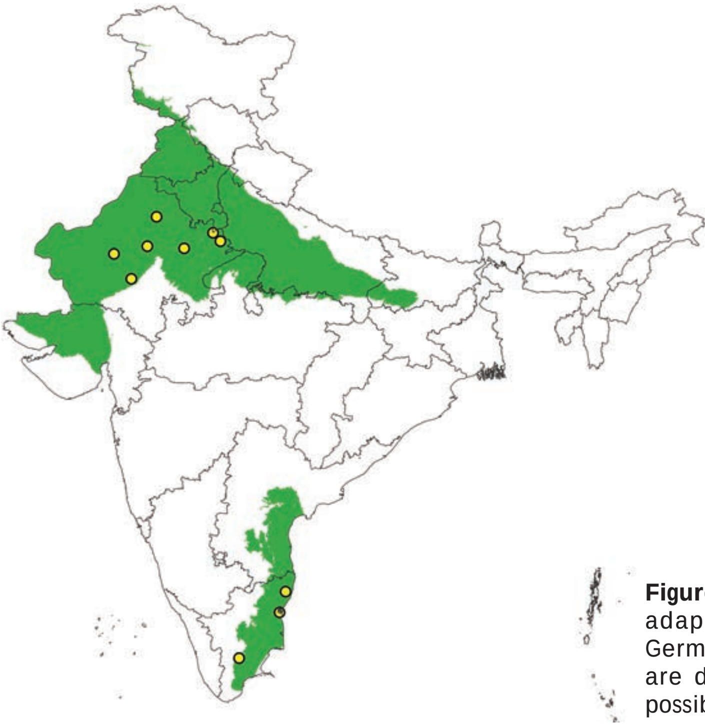


Figure 70: Predicted sites of sourcing pre-adapted sesame CWR germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

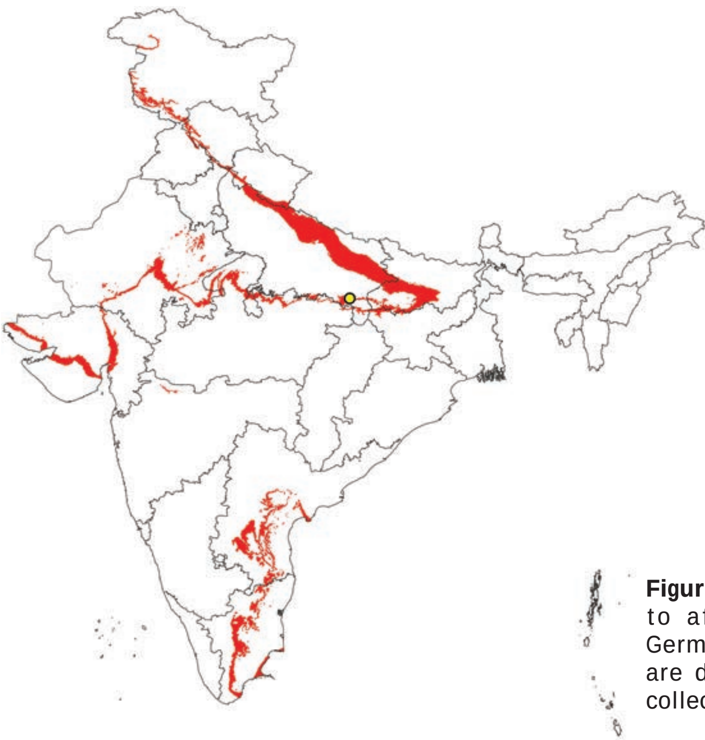


Figure 71: Vulnerable locations predicted to affect sesame CWR germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

CHILLI PEPPER

Chilli exhibits a lot of variability in terms of duration, use [green chillies to mature red chillies], ecological niche [coastal, trill], and botanical types [annual to perennial]. All these and much more influence how the germplasm are pre-disposed to predicted temperature increases [**Figure 72**]. Endemic populations could be in danger if such sites experience temperatures beyond threshold limits. Based on the climate maps, researchers could draw conclusion for collection-recollection and in-situ conservation [north-east] plans.

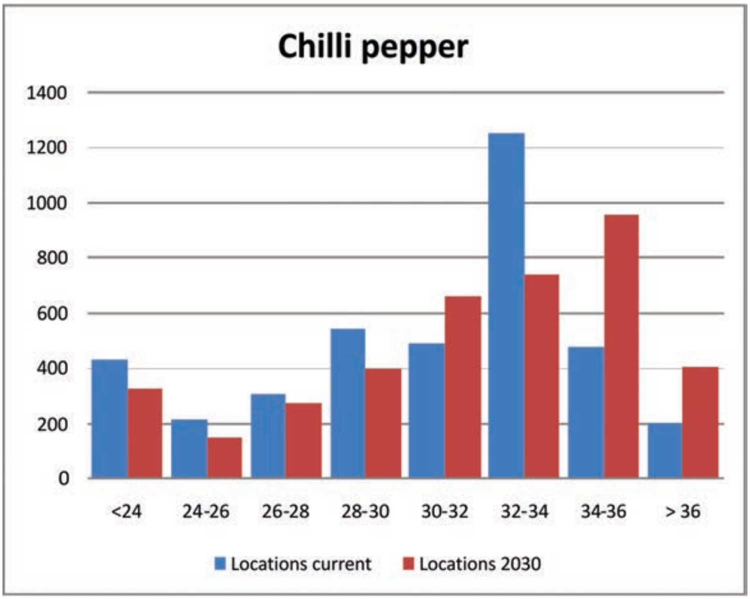


Figure 72: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of chilli pepper season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of chilli-pepper germplasm occurrence.

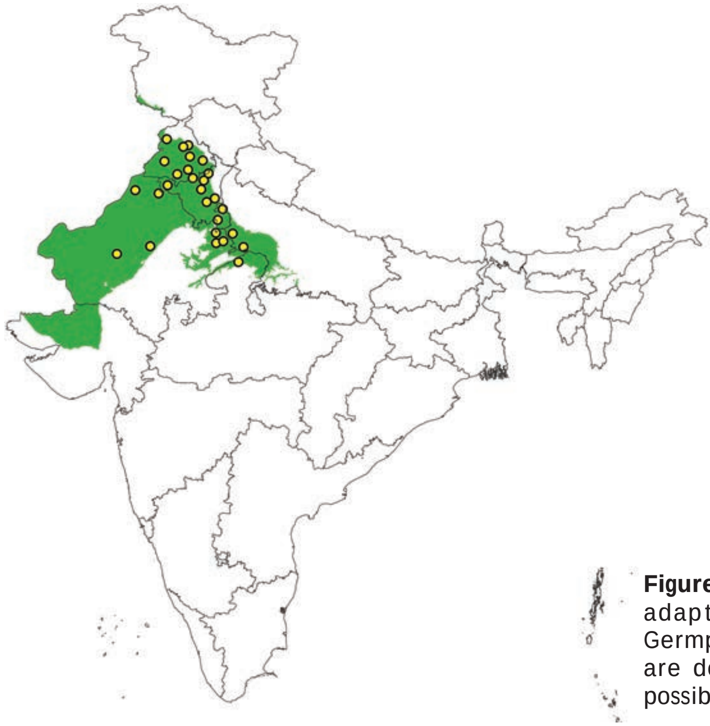


Figure 73: Predicted sites of sourcing pre-adapted chilli pepper germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

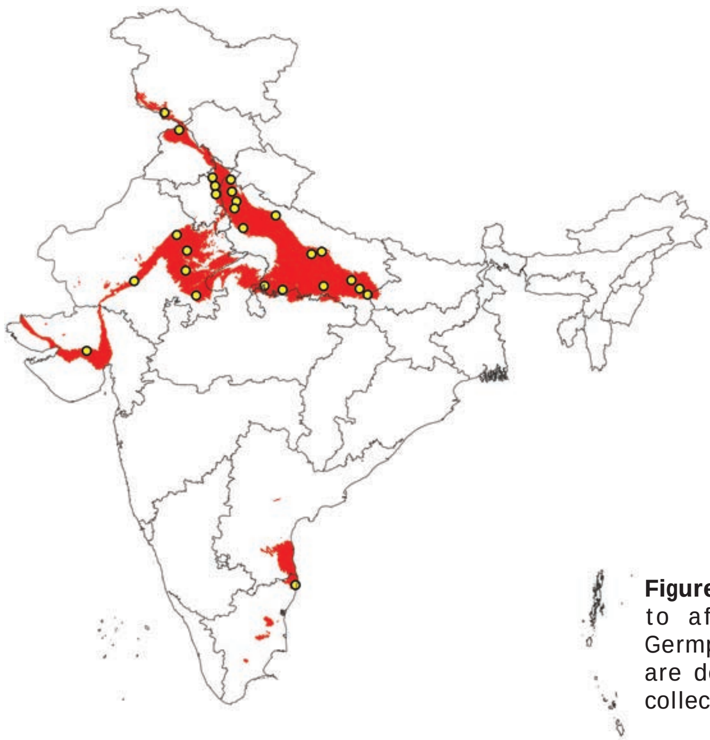


Figure 74: Vulnerable locations predicted to affect chilli pepper germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

BRINJAL

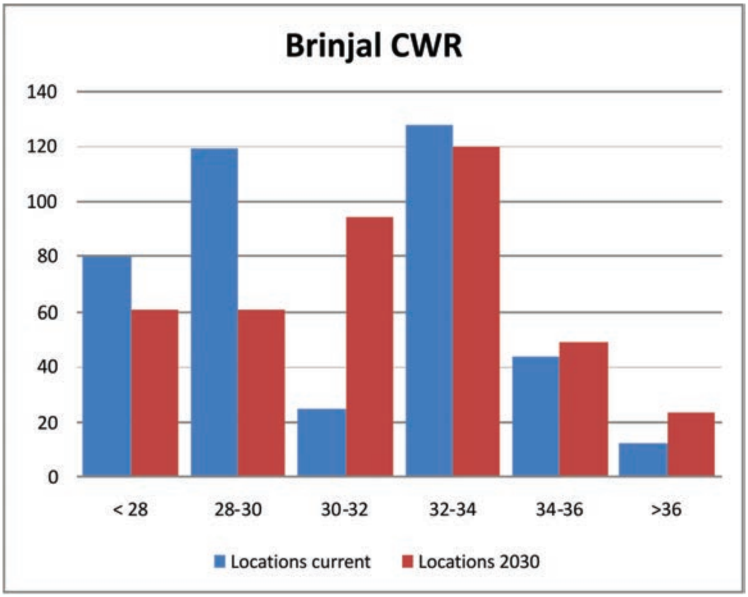


Figure 75: Number of locations of germplasm occurrence predicted to experience changes in the mean maximum temperature (x-axis) of brinjal CWR season. Y-axis depicts counts of germplasm collected, a proxy for actual sites of brinjal CWR germplasm occurrence.

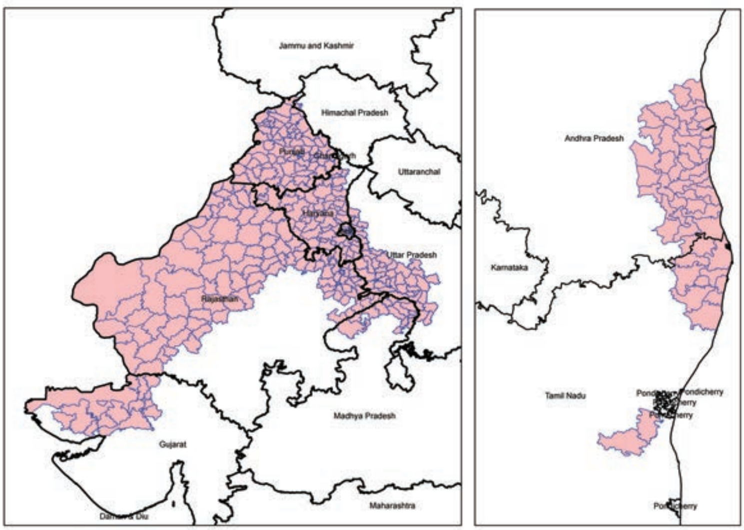


Figure 76: Suitable sites for exploring for pre-adapted brinjal CWR germplasm.

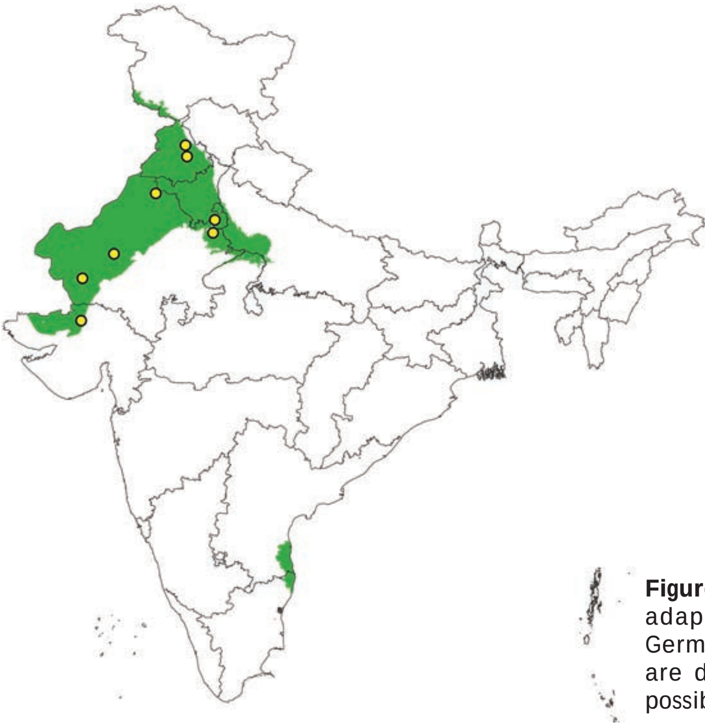


Figure 77: Predicted sites of sourcing pre-adapted brinjal CWR germplasm. Germplasm accessions already collected are depicted by yellow points to guide possible locations.

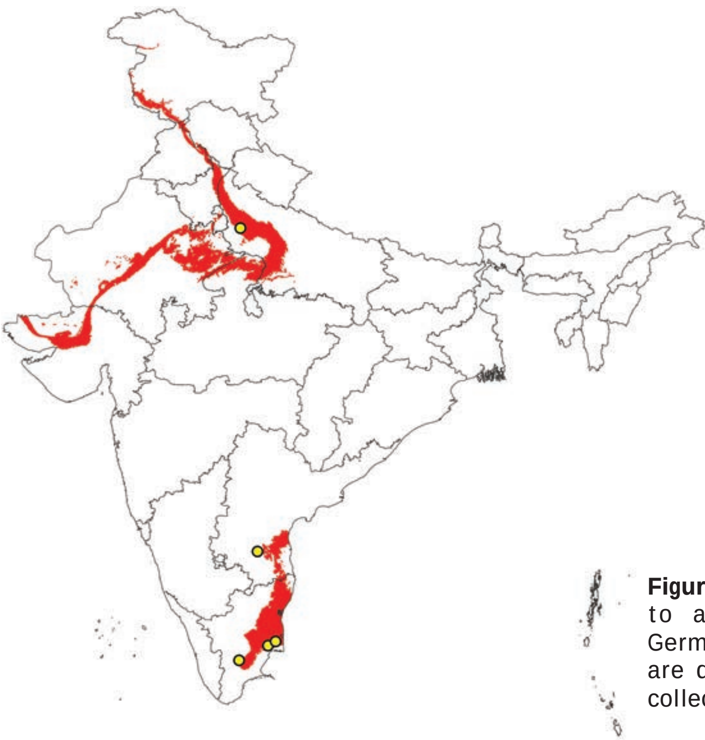


Figure 78: Vulnerable locations predicted to affect brinjal CWR germplasm. Germplasm accessions already collected are depicted by yellow points to guide collection activity.

6

Online information system

One of the objectives of the project was to generate climate maps [illustrated in chapter 4]. To make these maps available digitally and to provide users an opportunity to compare them with soil and climatic attributes, an application "PGR-Clim" was developed.

PGR-Clim : an online information system

PGR-Clim aims to provide an easy interface to access important climate change information with respect to plant genetic resources management. The alpha version of this web-based program is limited to collection information of all ten crops. The program allows the user to choose a crop and visualize how climate is predicated to change over time and stimulate them to assess impacts and measures. PGR-Clim is NBPGR's first informatics efforts towards linking PGR and climate change.

With PGR-Clim you can view germplasm collection sites in case of ten crops on:

- o India map
- o Soil map
- o Agro-ecological zones
- o Current and future temperatures
- o Current and future rainfall

PGR-Clim can accessed at http://www.nbpgr.ernet.in:8080/climate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Oil seed brassica
Sesame CWR
Chilli pepper
Brinjal CWR
Select Variable
AEZ
Soil
Temperature
Rainfall
Current
2020s
2050s
Get Map
Map
Kyrgyzstan
Tajikistan
Afghanistan
China
Pakistan
Nepal
Bhutan
Bangladesh
India
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Laos
Mumbai
Hyderabad
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7

Exploration and collecting germplasm

Based on the analysis illustrated in the previous section, exploration and collection missions were planned for all crops. Following mission were conducted:

1. Exploration and collection of landraces of pearl millet and sorghum from the parts of Rajasthan (25.10.2013 to 1.11.2013)

   Thirteen pearl millet and eighteen sorghum locally adapted cultivars were collected from villages. None of these locally adapted cultivars was in commercial cultivation. Often, farmers, particularly female folk, shared their saved seeds from the storage bins. For details of accessions collected see table at the end of this section.

2. Exploration for chickpea in the doab areas of Andhra Pradesh - Karnataka (11.8.2014 to 14.08.2014)

   One of the identified areas for chickpea germplasm collection was the transitional area of AP and Karnataka (on either banks of river Tungabhadra). With the available preliminary information, a visit of four days was planned keeping Raichur as major point. An occasion of socio-religious congregations was selected to interact with people. Startling facts came out of the interactions with farmers, farming women, farm laborers, community leaders, etc. Chickpea was no more grown in the area. Those few who cultivated chickpea had improved varieties. Farmers focus was cotton, a cash crop. In such scenario, finding landraces of chickpea in this region could not be achieved.

Figure 79. Farmers proudly showing the pearl millet traditional cultivars.

3. Exploration for wheat and chickpea in Madhya Pradesh (20.03.2015 to 25.03.2015)

Next exploration was carried out in Madhya Pradesh for rabi crops chickpea and wheat. Madhya Pradesh belongs to Central Zone of wheat cultivation where 75% of the wheat cultivated is rainfed. The best quality durum wheat is produced in this zone. Six chickpea accessions belonging to cultivars Kala Chana, Katila Chana, Khajiya Chana were collected (Table 4). Nine bread wheat accessions that were mainly 15-35 year old varieties (e.g. Sharbati, Harshita, Lokwan) adapted locally were collected. Ten accessions of durum wheat that were landraces or old varieties (Kala Ruyen, Safed Ruyen, KirnaiGehunand Kathiya) were collected.

Genetic identity and differences among collected landraces

Climate analog tools help predict locations based on past data on climatic variables. There are many other factors that influence the continued existence of landraces collected erstwhile from a specific location. If we find that the landraces are still in cultivation, then it becomes important to examine if there are any genetic differences among samples collected from different farmers of a given location. The fundamental purpose of employing climate tools is to capture as much genetic diversity as possible from the vulnerable locations to conserve them and to assemble climate ready pre-adapted germplasm to utilize them.

Figure 80. Sorghum traditional cultivars in the field and from the storage bin.

Figure 81. Religious function at village Manchali (Andhra Pradesh). Top left: Cow ritual (supposed to use traditional seeds of paddy, pulses and millets to feed cow, but they were missing); top right: Discussion with villagers in village Yeragera (Karnataka); Bottom: Drummers leading a procession of local festival.

Thirteen pearl millet and eighteen sorghum accessions were collected from villages of Rajasthan. Simple sequence repeats markers, gold standard in DNA fingerprinting, were employed to assess if the accessions collected from various farmers actually the same. Eighteen accessions of sorghum were screened using thirty markers and twelve were found to be informative. Similarly, thirteen pearl millet accessions were screened using seventeen markers and five were found to be informative. Except one marker in each case, all others were found polymorphic generating multiple allelic patterns. Similarly, nineteen wheat and six chickpea collections were assayed using ten microsatellite based ISSR markers. The results were only indications to diversity among landraces collected from a restricted area and need in depth analysis.

Based on climate prediction, forty-two villages were explored and 55 accessions belonging to four crop species were collected and conserved in the genebank

Table 7: Germplasm collected from locations identified based on climate prediction.

Crop	# Accessions	State	Villages from where collections were made
Pearl millet	13	Rajasthan	Bairkhon, Bidarkha, Bidoli, Danaw kala, Gazipur, Ghasipura, Hamidpur, Jakhrana, Khareri, Malai, Ramgarh, Ramgarhpachwara, Sawariyawala
Sorghum	18	Rajasthan	Agabli, Bairkhon, Devara, Dhankabund, Faagi, Goalpara, Hamidpur, Jaisinghpurawas, Jakhrana, Jaswant Nagar, Kakreli, Khareri, Krishna Nagar, Mainpurkidhari, Massit, Nagar, Nayagaon
Chickpea	5	Madhya Pradesh	Bhandeli, Bheelkhedi, Bhusi Meta, Laloi , Mundrapitamber, Nagaur
Bread Wheat	9	Madhya Pradesh	Alwaria, Bhandeli, Bhusi Meta, Kharbai, Khurania, Madnai, Nagaur, Nalkhera, TaasKhajiri
Durum wheat	10	Madhya Pradesh	Bheelkhedi, Hinotisadak, Kamapar, Kaudi, Koluwa, Kothri, Pippliyameera

8

Knowledge sharing: Capacity building

NBPGR organized a 5-day Regional Training Workshop on "GIS and Climate Analogue Tools for PGR Management and Enhanced Use" during 2-6, December 2013 at NBPGR, New Delhi. The aim of the Workshop was to impart contemporary knowledge on GIS, climate data, climate analogues and their applications in PGR management and utilization along with hands-on experience on various software, databases, clustering and analyses.

Participants of the workshop with organizers on the occasion of inauguration: Dr. PN Mathur, Dr. KC Bansal, Dr. JS Chauhan, Dr. Sunil Archak, Dr. M Dutta, Dr. PC Agarwal and Dr. RK Tyagi.

Objectives of the Workshop

- Impart contemporary knowledge on GIS, climate data, climate analogues and their applications in PGR management and utilization
- Hands-on experience on various software, databases, clustering and analysis
- Analysis of actual data, interpretation and decision making in PGR management
- The goal was to enhance the participants' capabilities to manage and utilize PGR effectively in the face of climate change demands.

Training Methods

The climate analogues approach is adopted to compare climate models with experimental data. Use of climate databases and software including the analogue tools connect sites with statistically similar climates, across space and time. A statistical index is used to systematically identify climate analogues across the world, for certain regions, or among specific locations. The exercise can be crop specific or season specific, and one can use any of the global climate models. Analogous sites are then compared to identify vulnerable sites and to propose collection and evaluation activities. Participants had an opportunity to listen to presentations by experts on select topics (25% of the time) and work hands-on (75% of the time).

Venue

Workshop was conducted at National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi. The training facility was created replete with overhead-projection system, adequate number of internet connections for all the participants and resource persons and a back-up wi-fi. The facility was created to cater to hands-on sessions.

Participants

The participants included eight persons from ICAR, one each from SAU and CSIR, and four from neighboring countries of the South East Asia (Vietnam, Laos and Cambodia) engaged in PGR management and interested in employing climate analogue tools. Indian participants were supported by dedicated funds available in the project whereas foreign participants were fully sponsored by our collaborator in the project, Bioversity

International. Trainees were from various disciplines including plant breeding, agronomy, statistics, botany, computer science, etc. The list is given below:

Dr. Moola Ram
Assistant ProfessorAgriculture
University, Sumerpur

Dr. Suma Mogali,
Scientist
UAS, Dharwad

Dr. Anuradha Sane
Pr. Scientist
IIHR, Bangalore

Dr. N Sivaraj
Pr. Scientist
NBPGR RS, Hyderabad

Mr. Shashikant Sharma
Technical Officer
NBPGR, New Delhi

Mr. Rajeev Gambhir
Technical Officer
NBPGR, New Delhi

Ms. Pheunphit Soisouvanh
Rice and Cash Crop Research Centre
Vientiane Lao PDR

Mr. Nguyen Tien Hung
Plant Resource Center
Ankhanh, Hoaiduc, Hanoi, Vietnam

Dr. Salini K
Scientist
CRIDA, Hyderabad

Dr. Amit Chawla
Scientist
IHBT, Palampur

Dr. Raj Pal Meena
Scientist
DWR, Karnal

Dr. DP Semwal
Sr. Scientist
NBPGR, New Delhi

Mr. AnkurBiawas
Scientist
IASRI, New Delhi

Mr. Mom Sovanna
CARDI, Phnom Penh
Kingdom of Cambodia

Mr. KhuatHuuTrung
Agricultural Genetics Institute
Hanoi, Vietnam

Pedagogy

During the training programme, about five hours of theory and 15 hours of hands-on sessions were held indicating 75% of time dedicated to practical learning. All the participants were asked to carry their laptops so that necessary software were loaded and input sample data transferred. They were provided with (i) copies of all the required manuals; (ii) research papers; and (iii) massive amount of data in a 16GB USB drive. Major way of training was interactive and the goal of keeping the training with a workshop flavor was successful.

The topics covered included: Role of GIS in PGR management and use; Introduction to GIS, databases, data preparation, geo-referencing data and importing data to a GIS platform; Applications of remote sensing technologies in climate change studies; Climate analogues: finding climate matching sites; Introduction to DIVA-GIS; installation and basic functions; PGR data analysis in DIVA-GIS; Use of geo-spatial tools for mapping of biodiversity; Introduction to climate databases (current and future) and their application for identification of climate analogue sites; Introduction to Maxent for prediction of analogue sites, etc. Exclusive time was allotted to group presentations and presentation by participants about their on-going work.

Our principal resource person was Ms. Sarika Mittra from Bioversity International and one objective of the programme was to develop similar core competence in NBPGR. Other resource persons who delivered lectures were Dr. Vasudeva Rao (Network coordinator of Agricultural Ornithology, Hyderabad) and Dr. RN Sahoo (Agricultural Physics, IARI).

A theory lecture in progress

A hands-on session in progress

Participants having a quick working-lunch

Participants discussing over tea

Participants received certificates from Dr. SK Datta, DDG (CS), ICAR

Dr. PN Mathur and Dr. KC Bansal interacted with participants

9

Conclusions and future prospects

Aim of the study "Utilization of *ex situ* collections and climate analogues for enhancing adaptive capacity to climate change" was to employ climate analog tools to super-impose location information of the genebank accessions on present and future climate maps. This exercise was carried out in ten crops. The analyses assumed that sites of past collections continue to cultivate the crop; and the local landraces must have adapted to the extant climate. The temperature maps illustrate that (*A*) there are germplasm collection sites in the current climate that already experience higher temperature and (*B*) there are locations that will experience higher temperature in the future climate. This information is not new for crop cultivation and various adaptation strategies have been suggested by researchers keeping in view yield and farmers' income. However, for PGR management, significant aspects are (i) adding value to the genebank collections from locations *A* described above as potentially pre-adapted accessions and (ii) documenting potentially vulnerable locations *B* described above and planning exploration and collecting exercise. These two sets of operations would allow the genebank to be ready with necessary germplasm accessions in the event of changed climate, even if the predictions are not 100% accurate.

The study has identified vulnerable locations for all ten crops and could list the sites (in terms of *taluks*) for exploration programmes to be planned. Exploration visits for four crops — sorghum, pearl millet, wheat and chickpea — were also accomplished collecting fifty five accessions. Potentially pre-adapted germplasm accessions were designated and a list is provided. Capacity building in terms of training the researchers to employ climate analog tools in their work was also accomplished. The results of the study are not lost in the report or publications. An open access interactive online application has been developed to view the climate maps generated in the study. With all these outputs, this study is only the beginning in applying climate analog tools for PGR management.

Evaluation of the accessions as potentially pre-adapted is not a straightforward exercise. Breeders would be interested to know which particular trait(s) of the genotype is contributing to the adaptability. In the absence of *future climate location* on-site evaluation is not possible. Furthermore, we need to employ better tools that take into consideration multiple factors. Identifying vulnerable sites based on better informed and robust tools and conducting exploration and collecting missions is expected to ensure collection and conservation of potentially threatened germplasm.An analysis of what to collect in terms of crop wild relatives and cultivated populations; extent of variation in terms of genetic variability; and contribution to adaptive capacity in terms of novel genes and alleles need to be carried out. Such studies will be able to evaluate the process of prediction based on climate models and their utility in PGR management.

10 Project team, funds utilization and publication

Contributors

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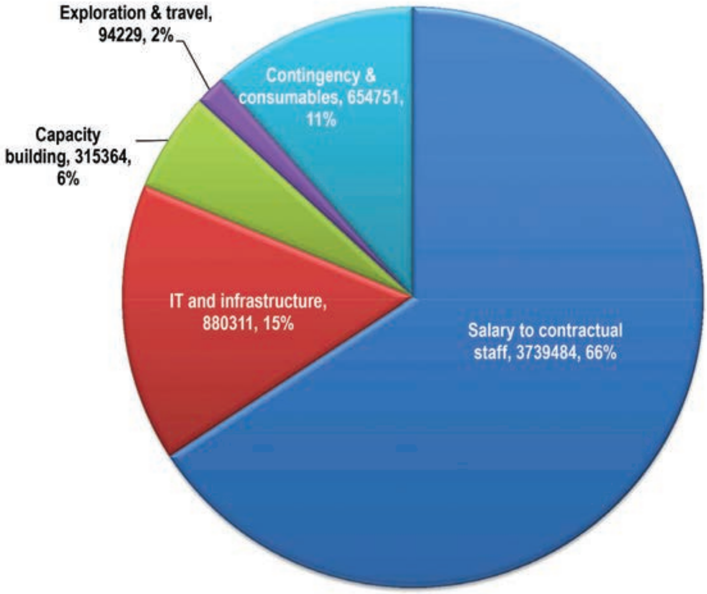
Funds utilization



Publications

1. Archak S (2013) *Use and conservation of PGR for climate change adaptation in India*. International Workshop on Seeds for Needs: Methodology and Future Strategy for Climate Change Adaptation, 15-16 Feb 2013, New Delhi, India.
2. Archak S (2014) Making genebanks 'climate-ready' to meet challenges of the future. https://ccafs.cgiar.org/blog/making-genebanks-climate-ready-meet-challenges-future.
3. Semwal et al. (2014) *Collecting millets landraces from climate hot-spots of Rajasthan using germplasm data and GIS tools*. Geomatrix'14: National Conference on application of geoinformatics in ruralm urban and climatic studies. 6-7 June 2014, Mumbai, India.
4. Archak et al. (2015) *Utilization of ex situ collections and climate analogues for enhancing adaptive capacity to climate change*. Climate smart agriculture 2015: Global Science conference 16-18 March 2015, Montpellier, France.
5. Archak et al. (2015) *Identifying plant genetic resources adapted to elevated temperature*. 3rd international plant physiology congress. 11-14 Dec 2015, New Delhi, India.
6. Archak S (2015) *Information management at NBPGR*. International Workshop on Genebank Operations and Advanced Learning (GOAL) Master Class, 16-20 Nov 2015, New Delhi, India.

ICAR-National Bureau of Plant Genetic Resources (NBPGR) is the nodal organization in India to carry out research, education and service activities in managing plant genetic resources. NBPGR houses the national genebank that is conserving more than 400,000 accessions belonging to various crops.

Its headquarters is located in New Delhi with ten regional stations spread across the country. NBPGR is a constituent organization under the Indian Council of Agricultural Research.

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