Indian J. Plant Genet. Resour. 35(3): 136–140 (2022)
DOI 10.5958/0976-1926.2022.00056.0

Application of Geographical Information System for PGR Management

N Sivaraj[1*], SR Pandravada[1], Anuradha Agrawal[2], V Kamala[2], V Celia Chalam[3] and K Anitha[1]
[1]*ICAR-National Bureau of Plant Genetic Resources, Regional Station, Hyderabad-500030, Telangana, India*
[2]*Agricultural Education Division, ICAR Headquarters, Pusa Campus, New Delhi-110012, India*
[3]*1-19-62, HIG B-1, A.S. Rao Nagar, Hyderabad-500062, Telangana, India*
[4]*ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110012, India*

Geographical information system (GIS) tools have enormous applications in management of plant genetic reources (PGR). GIS in conjunction with passport/herbarium/gene bank databases serves in geo-referencing, diversity distribution mspping and and predicting suitable sites for future collection of crop species and threatened taxa. They have been used in ecogeographic surveys for locating diversity, planning field exploration and collecting of PGR. They are also useful for identification of PGR conservation areas and individual species, species-rich areas and vegetation types that are not represented or under represented under conservation programs. In terms of biosecurity, GIS applications can be effectively used in locating hotspots, spread of pests and pathogens, develop early warning systems, build risk assessment models, assist in site specific protection measures etc. These technologies and applications developed in response to a wide range of needs are nowadays an indispensable tool in the management of PGR.

Introduction

Plant genetic resources (PGR) are most important for the continued existence and interests of humanity. A vast number of domesticated plant species are crucial to global food security, while other species are of great importance for purposes such as wood and bio-fuel production. In addition to the cultivated species, many wild plants still play an important role in meeting local needs for food, fuel, medicine and construction materials; crop wild relatives are also of special interest for crop breeding programmes. There are currently hundreds of underutilized plant species and varieties displaying traits of interest to meet present and future needs, while the value of many other plant species is yet to be discovered. Amongst the plethora of new age tools available for PGR management, geographical information system (GIS) is of immense importance for the improved understanding and monitoring of germplasm.

A GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows one to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts (www.esri.com). Thus, GIS is a database management system that can simultaneously handle data representing spatial objects and their attribute data. GIS can be effectively used in PGR management particularly in a) inventorisation/ mapping, b) collecting strategies, c) conservation strategies, d) characterization and evaluation, e) crop expansion strategies, f) documentation and g) plant quarantine.

Inventorisation/Mapping Strategies

Inventorisation/ Mapping Strategies Priority Action 1 of Global Plan of Action (GPA) calls for increased surveying and inventorying of plant genetic resources for food and agriculture. Datasets of PGR with attributes, identity and geo-reference data of relevant point locations are prerequisites for GIS mapping. Some of the GIS Software used for mapping are Arc-GIS, FloraMap, DIVA-GIS, Quantum GIS, GARP, ECOSIM, Degree, Climex, MaxEnt, HyperNiche, SAM, SPADE, gvSIG, Geo Da, ECOGEO, GEOQUAL etc.

GIS mapping has been successfully used in assessing biodiversity and in identifying areas of high diversity in *Phaseolus* bean (Jones *et al.*, 1997); coconut (Bourdeix *et al.*, 2005); wild potatoes (Hijmans and Spooner 2001); wild arachis (Jarvis *et al.*, 2003); horsegram (Sunil *et al.*,2008); *Jatropha curcas* (Sunil *et al.*, 2009); linseed (Sivaraj *et al.*, 2009; 2012); sesame (Spandana *et al.*, 2012), blackgram (Babu Abraham *et al.*, 2010); rapeseed-mustard (Semwal *et al.*,2012); piper (Parthasarathy *et al.*, 2008); *Canavalia* fatty acids (Sivaraj *et al.*, 2010); medicinal plants (Varaprasad *et al.*, 2007); *Spondias*

**Author for Correspondence: Email-N.Sivaraj@icar.gov.in*

(Miller *et al*., 2006), common bean (Sheikh Sultan *et al.*,2014) and agrobiodiversity in general for South East coastal India (Varaprasad *et al.,* 2008).

Collecting Strategies

Germplasm exploration and collecting are planned generally based on available databases of passport information. Passport information includes an identity to the collection, specific location of collection, details of habit/ habitat and other reference data. GIS can be effectively used in preparing distribution maps of species, probable location of the collection sites, gap analysis, analyzing diversity rich pockets etc. GIS can be used to link the passport database with district and state map layers to analyse what has been explored and collected and from where, and what are the gaps in germplasm collection (Fig.1). GIS and other specialized computer program (e.g. FloraMap) along with associated data can be used to map the predicted distribution of plant species or areas of possible climatic adaptation of organisms in the wild (Jones *et al.,* 2002). Also, GIS can play an important role in the management of large and complex PGR datasets (Guarino *et al.,* 2001). Guarino (1995) discusses the use of GIS to develop strategies for collecting germplasm. For example, collecting regions can be mapped to identify areas with desired ecogeographic attributes such as acid soils or climate extremes (Hart *et al.,* 1996). Thus, to plan future exploration programs which are trait specific/region specific GIS can be used effectively (Jones *et al.,* 1997; Greene *et al.,* 1999). Remote sensing satellite temporal data (time interval) in digital form can be used in impact assessment (by overlaying of different geospatial layers) studies, temporal changes to pinpoint status of collected threatened taxa diversity to find gaps and predict new areas for collecting.

Mapping the spatial distribution of target species along with the prevailing knowledge systems of communities can be effectively carried out using GIS. Traditionally tribal communities and farmers have been the custodians of PGR and developed huge knowledge systems over years. Indigenous traditional knowledge (ITK) associated with PGR, their time of cultivation, system of cultivation, its relation to the environment form a vital part of the tribal communities. Such knowledge systems which co-evolved with the nature provide the food and nutritional security of the tribal communities. Documentation followed by validation of PGr related ITK would make available such secure sources of ethnic systems to be harnessed for benefit of all.

Conservation Strategies

Complementary conservation strategies include the protection of wild species, plant populations and traditional crop varieties where they have evolved (*in situ* conservation), with the collection and preservation of inter- and intraspecific diversity in gene banks and botanical gardens (*ex situ* conservation). *Ex situ* genetic resource collections maintain germplasm in the form of seed or live plants, representing current, obsolete and primitive crop varieties, wild and weedy relatives of crop species, and wild species collected or augmented from around the world. GIS can be effectively used for genetic resources conservation in (i) identifying gaps for

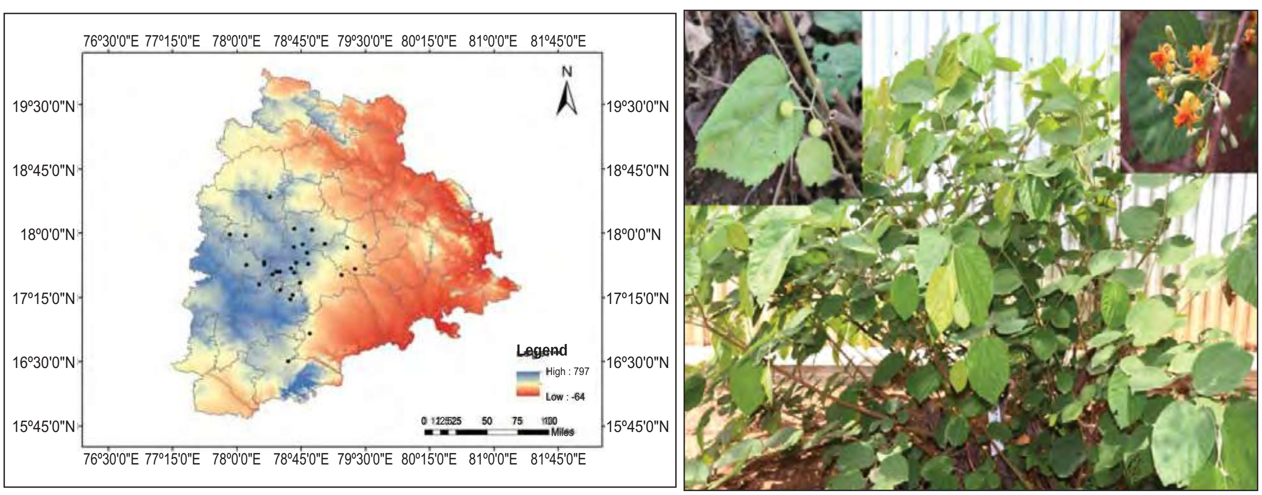

Fig. 1. Collection sites of *Phalsa*, an underutilized fruit crop from Telangana State, India

conservation in both *ex-situ* and *in-situ* and (ii) design and management of *on-farm in-situ* conservation sites. Further GIS, climate change models and geographical distribution data of crop plants and their wild relatives may be used to predict the impact of a changing climate on PGR, conservation and use. Geographical prediction of threatened plant distribution is important to genetic resource conservation planning and regional management decisions. Geospatial technologies are useful in predicting the spatial distribution of crop landraces and other target threatened species. It assesses multiple interdependent abiotic factors, e.g., solar radiation, air temperature, precipitation, and soil properties affecting plant distribution, models the environmental niches of target plants and refines their distribution maps for conservation planning.

PGR Characterization and Evaluation

Precise characterization and evaluation of PGR are a pre-requisite for their utilization. Germplasm utilization requires accurate characterization, evaluation and documentation of the material. PGR characterization and evaluation adds value to the germplasm and thereby, facilitates its utilization (Gautam, 2004). Largely germplasm evaluation involves the whole range of activities including germplasm multiplication, characterization, preliminary and detailed evaluation, regeneration, maintenance and documentation (Gautam, 2004). In all these activities GIS can play a crucial role by way of managing large data sets, identifying suitable locations for multiplication and evaluation of germplasm. In addition, identifying suitable locations for evaluating crops introduced from other countries could be done using GIS. Morphological descriptors/genetic variations may be linked with environmental attributes using GIS for selecting potentially useful germplasm accessions (Pederson *et al*., 1996). Data on physiological, morphological or genetic descriptors can be added to a punt map to investigate the spatial distribution of diversity (Guarino, 1995)

Crop Expansion Strategies

GIS can play a crucial role by way of managing large data sets, identifying suitable locations for multiplication and evaluation of germplasm introduced from other countries. Morphological descriptors/genetic variations may be linked with environmental attributes using GIS for selecting potentially useful germplasm accessions for crop expansion (Pederson *et al*., 1996). Ecological niche modelling studies on horticultural crops (Ceylon spinach, sorrel, roselle) using GIS had been worked out by Reddy *et al*. (2015a, b, c). Exotic germplasm of several agri-horticulutral crops (tef, kiwi, olive, dragon fruit etc.) can be introduced into suitable agro-climatic regions of our country after assessment using GIS (Fig. 2)

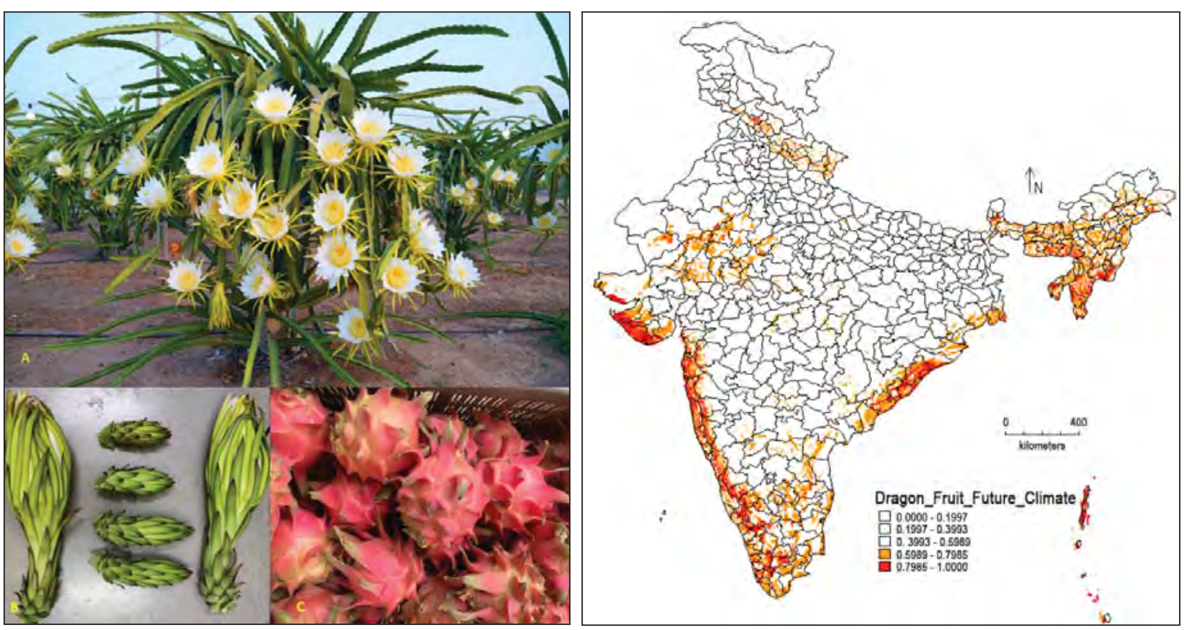

Fig. 2. Ecological niche model of climate suitable regions for dragon fruit cultivation in India (Future climate)

PGR Documentation

Stephanie L Greene and Thomas Hart state that "*Genetic resource databases could potentially serve as an information resource to a broader scientific community, providing relatively independent global data sets to meet the unique needs of environmental modelers. Multi-disciplinary collaboration would ensure the evolution of a set of databases useful to a broad range of professions*" (http://www.ars-grin.gov.) Genetic resource databases available with ICAR-NBPGR, ICAR-IIHR, and other agri-horticultural crop-based institutes in India could potentially serve as an information bank to the PGR researchers, providing the large PGR datasets to meet the requirements of breeders, environmental specialists. The information from these datasets can be used to generate and validate agro-ecological models developed and to predict the agronomical potential of germplasm accessions of agri-horticultural crops. Based on the existing records indicating the historic availability of the various crops and their wild relatives, the distribution and use of crop species including adoption of new cultivars or new crop species could be assessed. Passport information of the germplasm accessions including the presence of associated species can be useful in preparation of predicted distribution maps of wild or cultivated species.

Plant Quarantine Strategies

GIS has been applied for pest monitoring and detection through data visualization and query, survey data collection, management, and risk pathway analysis. It can also help to determine areas that have highest risk for a pest introduction. Prediction models can be generated for detection in case of invasive alien species and to quantify area change in their spread. The use GIS in PQ is important as it provides economic benefit, is a proactive approach in safeguarding agriculture, helps in quality control assistance and decision support system. Recent examples include (i) Adult grasshopper hazard analysis (in USA) to identify patterns in grasshopper survey that may predict future population increases, as related to environmental conditions (*i.e.*, climate, soil, vegetation) (ii) to identify areas most likely to have Asian gypsy moth and to improve and/or validate existing AGM trapping locations trapping (in USA) (iii) Sugarcane woolly aphid spread in southern India and (iv) papping of pest distribution data (from pest interceptions of import quarantine)

Future Thrusts

- GIS can be used in gap analysis, planning and execution of future exploration programs at national level for effective conservation and utilisation of threatened PGR.
- PGR passport data information, satellite data spectral signature and climate analogue tools could be used in diversity distribution mapping and prediction of diversity rich areas.
- GIS coupled with hyperspectral remote sensing can be used in distinguishing and identification of threatened PGR for effective conservation measures.
- High spatial resolution (60 cm) satellite data can be used in mapping of disease symptoms in threatened species at fine grid level.
- Ecological niche models/species distribution models for all the crop landraces and other plant genetic resources to be constructed for effective conservation in the changed climatic regime.

References

Abraham B, Kamala V, Sivaraj N, Sunil N, Pandravada SR, Vanaja M, Varaprasad KS (2010) DIVA-GIS approaches for diversity assessment of pod characteristics in black gram (*Vigna mungo* L. Hepper). *Curr. Sci.* **98(5):** 616-619.

Bourdeix R, Guarino L, Mathur PN and. Baudouin L (2005) Mapping of coconut genetic diversity. In: Pons Batugal, Ramanatha Rao V, Jeffrey Oliver (eds) Coconut Genetic Resources. IPGRI. pp. 32-43.

Dikshit N, Abdul Nizar, M and Sivaraj N (2012) Evaluation and diversity analysis of safflower germplasm in relation to morpho-agronomic characteristics. *J. Oilseeds Res*. 29 (Special Issue): 17-23.

Gautam PL (2004) Trends in plant genetic resource management. In: Dhillon BS, Tyagi RK, Arjun Lal (eds) *Plant genetic resource management*. Narosa Publishing House, New Delhi pp 18-30.

Greene S, Hart T and Afonin A (1999) Using geographic information to acquire wild crop germplasm: II. Post collection analysis. *Crop Sci*. **39**: 843-849.

Guarino L (1995) Geographic information systems and remote sensing for the plant germplasm collector. In: Guarino L, Ramanatha Rao V and Reid R (eds) Collecting Plant Genetic Diversity. Technical Guidelines. CAB International, Wallingford, UK, pp. 315–328.

Guarino L, Jarvis A, Hijmans RJ and Maxted N (2002) Geographic information systems (GIS) and the conservation and use of plant genetic resources. In: Engels JMM, Rao VR, Brown AHD, Jackson MT (eds) *Managing Plant Genetic Diversity*. IPGRI, Rome, Italy pp 387-404.

Guarino L, Maxted N and Sawkins M (1999) Analysis of geo-referenced data and the conservation and use of plant genetic resources. In: Greene SL and Guarino L (eds) *Linking Genetic Resources and Geography: Emerging Strategies for Conserving and Using Crop Biodiversity*. CSSA Special Publication No. 27. ASA and CSSA, Madison, Wisconsin, pp. 1–24.

Hart TS, Greene SL and Afonin A (1996) Mapping for germplasm collections: Site selection and attribution. Proc. Third Int. Conf. 'Integrating GIS and environmental modeling'. NCGIA, Santa Barbara, CA.

Hijmans RJ and Spooner DM (2001) Geographic distribution of wild potato species. *Amer. J. Bot.* **88:** 2101-2112.

Hijmans RJ, Guarino L, Cruz M and Rojas E (2001) Computer tools for spatial analysis of plant genetic resources data 1. DIVA-GIS. *Plant Genetic Resourc. Newslett.* **127**: 15-19.

Jarvis A, Ferguson ME, Williams DE, Guarino L, Jones PG, Stalker HT, Valls JFM, Pittman RN, Simpson CE and Bramel P (2003) Biogeography of wild *Arachis*: assessing conservation status and setting future priorities. *Crop. Sci.* **43**: 1100-1108.

Jones PG, Beebe SE, Tohme J, Galway NW (1997) The use of geographical information systems in biodiversity exploration and conservation. Biodiversity and conservation **6**: 947-958.

Jones PG. and Gladkov A (1999) FloraMap: A Computer Tool for the Distribution of Plants and Other Organisms in the Wild. CIAT, Cali, Colombia.

Jones PG, Guarino L, Jarvis A (2002) Computer tools for spatial analysis of plant genetic resources data: 2. FloraMap. *PGR Newsletter* **130:** 1-6.

Miller, Allison J, Knouft JH, (2006) GIS-based characterization of the geographic distributions of wild and cultivated populations of the Mesoamerican fruit tree *Spondias purpurea* (Anacardiaceae). *Am. J. Bot.* **93:** 1757-1767.

Parthasarathy U, George J, Saji KV, Srinivasan V, Madan MS, Mathur PN, Parthasarathy VA (2008) Spatial analysis for Piper species distribution in India. Plant Genetic Resources Newsletter. 147:1-5.

Pederson GA, Fairbrother TE, Greene SL (1996) Cyanogenesis and climate relationships in U.S. white clover germplasm collection and core subset. *Crop Sci*. **36:** 427-433 99

Reddy MT, H Begum, N Sunil, SR Pandravada, N Sivaraj and S Kumar. 2015a. Mapping the climate suitability using maxent modeling approach for Ceylon spinach (*Basella alba* L.) cultivation in India. *J. Agric. Sci.* **10(2):** 87- 97.

Reddy MT, Begum H, Sunil N, Pandravada SR, Sivaraj N. (2015b) Assessing climate suitability for sustainable vegetable Roselle (*Hibiscus sabdariffa* var. *sabdariffa* L.) cultivation in India using MaxEnt model. *Int. J Agric. Biol.* **1(2):** 62-70.

Reddy MT, Begum H, Sunil N, Pandravada SR, Sivaraj N and Kumar S. (2015c) Predicting potential habitat distribution of sorrel (*Rumex vesicarius* L.) in India from presence-only data using Maximum Entropy Model. Open Access Library Journal, 2: e1590. http://dx.doi.org/10.4236/oalib.1101590

Sheikh Mohammad Sultan, Sher Ahmad Dar, Suheel Ahmad D and Natarajan Sivaraj (2014) Diversity of common bean in Jammu and Kashmir, India: a DIVA geographic information system and cluster analysis. *Int. j. appl. nat. sci.* **6(1):** 226-233.

Semwal DP, Bhandari DC, Bhatt KC and Ranbir Singh (2012) Diversity distribution pattern in collected germplasm of Rapeseed-Mustard using GIS in India. *Indian J of Plant Gene. Resour.* **26(1):** 76-81.

Sivaraj N, Sunil N, Pandravada SR, Kamala V, Vinod Kumar, Rao BVSK, Prasad RBN, Varaprasad KS (2009) DIVA-GIS approaches for diversity assessment of fatty acid composition in linseed (*Linum usitatissimum* L.) germplasm collections from peninsular India. *India. J. Oilseeds Res.* **26:** 13-15.

Sivaraj N, Sunil N, Pandravada SR, Kamala V, Rao BVSK, Prasad RBN, Nayar ER, Joseph John K, Abraham Z, Varaprasad KS (2010) Fatty acid composition in seeds of Jack bean [*Canavalia ensiformis* (L.) DC] and Sword bean [*Canavalia gladiata* Jacq.)DC] germplasm from South India: A DIVA-GIS analysis. *Seed Technol* **32(1):** 46-53.

Sivaraj N, Sunil N, Pandravada SR, Kamala V, Vinod Kumar, Babu Abraham, Rao, BVSK, Prasad RBN and Varaprasad KS (2012) Variability in linseed (*Linum usitatissimum*) germplasm collections from peninsular India with special reference to seed traits and fatty acid composition. *Indian J. Agric. Sci.* **82 (2):** 102-105.

Sivaraj N, Pandravada SR, Dikshit N, Abdul Nizar M, Kamala V, Sunil N, Chakrabarty SK, Mukta N, Varaprasad KS (2012) Geographical Information System (GIS) approach for sustainable management of Safflower (*Carthamus tinctorius* L.) genetic resources in India. *J. Oilseeds Res.* **29** (Special Issue): 45 - 49.

Spandana B, Sivaraj N, John Prasanna Rao G, Anuradha G, Sivaramakrishnan S, Farzna Jabeen (2012) Diversity analysis of sesame germplasm using DIVA-GIS. *Journal of Spices and Aromatic Crops* **21(2):** 145-150.

Sunil N, Sivaraj N, Anitha K, Babu Abraham, Vinod Kumar, Sudhir E, Vanaja M and Varaprasad K S (2009) Analysis of diversity and distribution of *Jatropha curcas* L. germplasm using Geographic Information System (DIVA-GIS). *Genetic Res. Crop Evol.* **56:** 115-119.

Sunil N, Sivaraj N, Pandravada SR, .Kamala V, Raghuram Reddy P, Varaprasad KS (2008) Genetic and geographical divergence in horsegram germplasm from Andhra Pradesh, India. Plant Genetic Resources: Characterization and Utilization **7(1):** 84-87.

Varaprasad KS, Sivaraj N, Mohd Ismail. Pareek SK (2007) GIS mapping of selected medicinal plants diversity in the Southeast Coastal Zone for effective collection and conservation. In: Janardhan Reddy K, Bir Bahadur, Bhadraiah B, Rao MLN (eds) Advances in Medicinal Plants. Universities Press (India) Private Ltd, pp 69-78.

Varaprasad KS, Sivaraj N, Pandravada SR, Kamala V, Sunil N (2008) GIS mapping of Agrobiodiversity in Andhra Pradesh,. Proceedings of Andhra Pradesh Akademi of Sciences. Special Issue on Plant wealth of Andhra Pradesh pp 24-33. Vavilov NI (1951) The Origin, Variation, Immunity and Breeding of Cultivated Plants. Ronald Press Company, New York.