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A Review of Landraces' On-farm Conservation, Practices and Management: An Indian Perspective

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Plant genetic resources are the most valuable and essential basic raw materials to meet the current and future needs of crop improvement programs to enhance the genetic base of a crop. With erosion playing a crucial role in diminishing diversity, different conservation methods come to play a

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massive role in preserving these resources. Thus, in the present paper, the authors tried to provide a gist about the on-farm conservation activities practiced in India and the importance of on-farm diversity in terms of economic importance. Different key words like on-farm conservation, landraces, custodian farmers, on-farm diversity were used to collect the different articles on on-farm conservation. Research articles from different states and regions around the country were gathered to collate the data and knowledge. In managing the key farm resources, the role of community seed banks, kitchen gardens, custodian farmers, their communities and organizations has been highlighted, along with a few case studies of on-farm conservation activities across the sites in the country. With the collection and documentation of on-farm material for genebanks and databases, it may provide easy access to on-farm material for potential users in the future. Providing incentives, identifying key problems, and providing necessary facilities may sustain on-farm conservation.

Keywords: Conservation; diversity; custodian farmers; landraces; documentation.

1. INTRODUCTION

More than 1,740 genebanks conserve over 7.4 million crop samples around the world, yet genebank conservation cannot act alone due to some constraints and conserves only a limited diversity of staple crops, commodity crops, and their wild relatives [1,2]. It is consequently on-farm where the bulk of the diversity of the most crop species is maintained. Moreover, on-farm strategies preserve indigenous knowledge and cultural value associated with crops, along with an active process of adaptation to climate change, new pests and diseases, and other socio-cultural contexts, that are not possible by *ex situ* methods [3].

According to Ford-Lloyd and Jackson [4], plant genetic resources (PGRs) constitute the fundamental basis of crop development and long-term global food, nutrition, and livelihood security. With genetic constituents having real and potential value, these vital raw materials help to meet the present and future demands of agriculture. These abundant germplasm collections, historically maintained by farming communities, are known by many names (traditional varieties, native cultivars, landraces, heirloom varieties, and folk varieties). Of them, the term "landraces" has evolved to refer to historically conserved and domesticated germplasm originating from different crops and different regions [5]. Additionally, this article uses these terms interchangeably to refer to the same content.

As an alternative to in-situ and ex-situ methods, on-farm conservation has gained recognition, considering the importance of maintaining diversity in all its forms. On-farm conservation of agricultural biodiversity in traditional agricultural, horticultural, or agri-silvicultural cultivation systems refers to farmers maintaining traditional crop varieties (landraces) or cropping systems in their fields and uncultivated plant communities, which are their natural habitats. [3,6]. This strategy offers several advantages, such as facilitating the progressive accumulation of traits for adaptation to specific eco-geographical regions, enabling evolution to proceed in a natural context, and meeting the demands of local tribes, groups, and populations. India, being a diverse rich country, offers much diversity in the farm fields to meet the demands of the communities as well as the potential users of crop improvement programs. Therefore, the authors tried to give a brief account of on-farm conservation activities, strategies, and management aspects in the Indian context. Additionally, the significance of community seed banks, kitchen gardens, and custodian farmers in disseminating native seeds and associated knowledge, along with some case studies, were documented in different parts of the country.

Research articles from different regions around the country were gathered to collate the information. Research articles from the 1980s and 1990s to date were assembled to write the present review article to give comprehensive and all-inclusive information on on-farm conservation and its activities in India. Different key words like on-farm conservation, landraces, custodian farmers, and on-farm diversity were used in Google Scholar to collect the different articles on on-farm conservation. Case studies from different states and regions were included to represent wide-ranging data and knowledge. Different aspects, like kitchen gardens and home gardens, community genebanks, and the concept of and the concept of custodian farmers, were included, along with NGOs working on on-farm conservation.

2. IMPORTANCE OF ON-FARM DIVERSITY IN INDIA

On-farm conservation is distributed throughout the Indian subcontinent, and major activities are observed mainly in diversity-rich areas such as the North-East region [7], Hore, 2005), Eastern India [8,9], the Deccan Plateau [10,11], and hilly states of the Himalaya [12,13]. On-farm conserved material provides a source of livelihood to the poor and marginal farmers as it requires cost-friendly inputs (farm yard manure, less water requirement) and farm conserved seeds through time and space [14] On-farm diversity also helps to diversify the cropping systems to reap the benefits of harvest and to mitigate the failure of other crops (unable to cope with changing climates or the attack of new pests and diseases). Observations of agricultural performance after extreme climatic events in the last two decades have revealed that resiliency to climate disasters is closely linked to the high level of on-farm biodiversity, a typical feature of traditional farming systems [15].

On-farm diversity provides the basic material to meet the requirements for crop improvement and breeding programs and acts as a source of traits for various biotic stresses like pests and disease resistance [16]. Also able to adapt to dynamic climatic changing scenarios such as disease outbreaks, droughts, and submerged conditions [17,18]. In fact, many scientists have used these on-farm conserved landraces in breeding programs for enhanced variety for a particular trait. Umakanth et al*.* [19] conducted experiments on rice landraces collected in the North-East region and identified many cultivars possessing genes for rice's *Magnaporthe* disease resistance (blast disease). Some on-farm material acts as a source material for some abiotic stresses like salt water and submerged tolerance [20]. For example, *Kagga* and *Pokkali* are rice landraces that grow well in salt water and submerged conditions available in the coastal regions of Karnataka and Kerala, respectively [21,22].

Though the country has been self-sufficient with food grain production since the green revolution, and recently the nutrient deficiency is emerging as a major threat in modern society. In order to rectify the nutrient deficiency, on-farm cultivars are a greater source of enhanced nutrients and minerals than normal breed varieties and hybrids [23]. For instance, Roy et al*.* [24] investigated the rice landraces available in the farms of West Bengal and Odisha and found them to have a higher concentration of minerals and vitamins than the modern cultivars. In a similar fashion, the custard apple landraces collected from different parts of Madhya Pradesh possess a good amount of nutritious minerals and other health benefits [25]. Meanwhile, the history says that many of the landraces found in farmers' fields are proven to be of medicinal value in Indian traditional medicine as well [26]. Arun [27] conducted scientific experiments on *Navara* rice landrace from Kerala state and provided its health benefits for treating neuromuscular illnesses and digestive issues. The oil is used to treat a range of aches and pains, including paralysis and rheumatoid arthritis. Many other pieces of evidence are available regarding the nutritional and health benefits of on-farm crop diversity throughout the country. Native cultivars were found in traditional cropping systems, and many tribal communities around the country use them as a part of their diet [28]. To complement to, Bisht [29] stated that traditional crops and landraces are important sources for addressing malnutrition and food-related disorders.

India is a country known for its traditions and cultures that have been practised for centuries. Diversity in crops and their varieties, especially landraces, take a prominent part in cultural festivities and their celebrations throughout the country. For example, the '*Harela*' festival is celebrated using 12 types of crops and their native seeds in Uttarakhand state [30]. People in Maharashtra's Nandurbar also use local cultivars during *puja* offerings in festival celebrations [31]; similar celebrations and conservation aspects were observed in West Bengal as well [32]. Tribal communities in Odisha's Koraput celebrate agricultural rituals throughout the year and use specific native rice varieties for each and every rite, showing the landraces' strong cultural association [33]. Another study from the North-East region of India revealed the rich cultural significance of rice landraces among the *Nagas*. Rice landraces played important roles in ethnic cultures, festivals, and religious ceremonies in Nagaland [34].

Since the diversity in the farms offers many benefits to the farmers yet faces many threats like monocropping or monoculture and the necessity to increase production, farmers have been turning towards high-yielding varieties (HYVs) and hybrids since the green revolution, and many scientists have agreed upon this [35]. Recent emerging technologies in agriculture, such as industrial agriculture and contract

farming, offer better livelihood opportunities to farmers. This, in turn, neglects the traditional varieties and landraces, which lead to their erosion and associated traditional farming systems over the years.

3. PRINCIPLES AND CHARACTERISTIC FEATURES OF ON-FARM CONSERVATION ACTIVITIES IN INDIA

On-farm conservation is part of *in situ* conservation practice, where the role of the farmer is crucial in conserving the traditional diversity of crops. Farmers preserve unique varieties of native seeds that vary in color, size, flavor, shape, demand in the local marketplaces, and their utilization [33,36]. Women are more concerned about tastes, color combinations, and nutritional value. Conversely, men tend to work on bigger farms, focus on yield, and select a small number of high-producing cultivars whose harvest is mostly for the market [37]. As a result, women are crucial to farm conservation efforts and the preservation of native seeds [38]. The pivotal role of women in on-farm conservation has been reported across various states like Tamil Nadu [39], Maharashtra [31], Karnataka (Sahajasamrudha.org), Odisha [33], and the Western Himalayas [40].

India is one of the nations with the highest levels of biodiversity, and agricultural biodiversity is essential to enhancing agricultural output and raising farmer incomes. In particular, the lives of poor and marginal farmers greatly depend on the diversity found on farms. Therefore, an attempt is made to provide a few essential aspects of on-farm conservation from an Indian perspective in the section that follows.

1. On-farm conservation is mainly done by custodian farmers, traditional and/or tribal communities, and a few NGOs supporting them (BAIF, Navdanya).
2. It mainly aims to conserve farmers' varieties, landraces, and traditional varieties that are widely grown, promoted, and used by farmers themselves.
3. Farmers are the main stakeholders in on-farm conservation; they retain the heirloom varieties over time in an environment where they receive unique properties through sowing, growth, and material donation or sale. They additionally have concerns about the management and preservation of agro-ecosystems.
4. Public authorities have a distinct role in promoting, organizing, coordinating and monitoring *in situ* on-farm conservation activities. They provide financial, administrative, legal, and technical support to on-farm conservation activities. Furthermore, they support the registration and protection of farmers' varieties and are involved in the setting-up and monitoring of policies [41].
5. It is mostly devoid of improved varieties and hybrids, which are in mainstream food grain production nowadays.
6. Most of the on-farm conservation practices follow traditional agri-horticulture systems, which are devoid of fertilizers, pesticides, and other agri-chemicals [14].
7. Small and marginal farmers are more benefitted as they are the ones involved in subsistence agriculture for their self-sustenance and understand the importance and qualities of landraces.
8. Farmers select variations to improve yield, adaptation, and quality. The conservation methods they follow will help in improving their capacity to increase farmers' income and seeds for their next season.
9. Many farmers, especially for horticulture crops, run local nurseries to raise seedlings of native varieties to distribute to the farmers, who in turn provide livelihood to the family [39,42].

Ethnic traditional culture practices are a crucial foundation for increasing the genetic diversity of landraces and implementing on-farm conservation. Through the use of community biodiversity registers, it has been observed that a few community seed banks are acting as a repository for indigenous knowledge as well [43]. It was found that each custodian farmer had a unique set of motivations, objectives, pastimes, and social skills. These differences have an impact on their efforts to protect crop genetic diversity and associated traditional knowledge. If custodian farmers did not conserve their traditional varieties, they would disappear because the rest of the community members do not know how to conserve them. This suggests that custodian farmers maintain essential knowledge required to cultivate and validate traditional crop diversity [24]. Meanwhile, traditional knowledge about the indigenous cultivars will help to explore the scientific basis of the nutraceutical values of the traditional cultivars by the plant breeders for sustaining food as well

as nutritional security and overcoming future challenges.

4. METHODS AND STRATEGIES WITH CASE STUDIES

A number of community-based strategies and methods have been developed and followed in India for on-farm conservation activities. Their awareness to save native seeds is improving their performance through participatory plant breeding (PPB), community seed banks (CSBs), kitchen garden concepts, and other seed saving initiatives, and increasing their value through market-based interventions [37]. Each one of the above is doing its own thing to conserve the seeds of native landraces and continue to grow in the future as well.

4.1 Kitchen Gardens/Home Gardens

Home gardens are well-established land-use systems within the larger farming systems, maintained very close to the homestead. Home gardens are living gene banks and a reservoir of plant genetic resources that preserve landraces, cultivars, rare species, endangered species, and species neglected in larger ecosystems.

Sridhar and Subramanian [44] set up a kitchen garden concept using a package that promotes the incorporation of indigenous varieties of vegetables and fruits in Tamil Nadu. In the arrangement, all the beneficiaries have learned about home gardening and cultivated indigenous varieties of vegetables for home consumption. Women's role was highlighted, and their efforts in establishing an organic kitchen garden and knowledge about seed production have improved [38]. Kitchen gardens contribute to conserving the local indigenous varieties of vegetables and greens, and this serves as a local gene pool and micro-conservation center.

Farmers in the Goa and Konkan regions of Maharashtra have a conventional, multitiered, homestead system of gardening called *kulagar*, inherited from their ancestors, to cultivate and conserve the local crop plants near their household. It is an integrated system with the skeletal component, such as areca nut palms, along with other plantation crops, spices, fruits, local vegetables, medicinal and aromatic plants, and flower crops. *Kulagar* has its own identity and culture. The Konkani word '*kull'* means family and '*aagar'* means storehouse. The farmers are routinely conserving the local genotypes and landraces in the *kulagars*. Awareness and appreciation in the form of awards to conserve and utilize the local genetic resources and spread awareness to the people regarding the local resources by show casing it as a part of agri-tourism [45].

Accordingly, the package developed for kitchen gardens should contain indigenous vegetable varieties to be distributed to community members and other self-help groups. Thus, the kitchen garden plays an essential role in disseminating native seeds and promoting their cultivation. To make these home gardens self-supporting by creating a mechanism for strengthening local seed supply systems for the long-term sustainability of home gardens in agrobiodiversity management.

4.2 Community Seed Banks (CSBs)

Community Seed Banks (CSBs) are part of seed-saving initiatives and are interlinked subjects that go hand-in-hand. Due to modern agriculture and the intervention of hybrids, traditional crop diversity is disappearing at a faster rate. There is an urgent need to document, collect, and conserve neglected and underutilized germplasm resources through community participation, which play a very vital role in sustainable agriculture. CSBs are part of seed-saving initiatives where farmers sow, harvest, distribute, and conserve the native seeds in household seed banks and in CSBs [46]. In various parts of the country, farming communities are involved in saving local cultivars for their adaptation, local cuisine preparation, and special cultural and religious significance. Here, CSBs are playing a prominent role in disseminating and preserving the seeds from season to season and, in certain cases, from generation to generation.

Among local communities, farmers managed the seed bank and followed a barter system. A farmer who collected seed from the bank had to return double the amount of seeds (or as per the fixed amount) after the harvest next year. This instilled a sense of ownership in everyone who traded with the community seed bank. Community seed banks also helped to restore and revive many nearly extinct varieties. This particularly proved useful in the age of climate change, as farmers needed varieties that withstand extreme weather events such as drought and floods [47].

The CSB initiative has grown over the decades and is a multi-state initiative with farmer groups involving farmers actively in several states: Kerala, Bihar, Chhattisgarh, Madhya Pradesh, Odisha, Rajasthan, Karnataka, and West Bengal. In India, different organizations and NGOs are involved in the setting up of community seed banks in different parts of the country. For example, BAIF set up CSBs for various crops like rice, millets, beans, pulses, and wild vegetables in the Jawhar (Palghar), Akole (Ahmednagar), Junner (Pune), Dhadgaon (Nandurbar), Etapalli (Gadchiroli), Kudal (Sindudurg) blocks of Maharashtra and also in Champawat (Uttarakhand), Dangs (Gujarat), and Sambalpur (Odisha) (citation). Navdanya has set up 150 community seed banks in 22 states of India in the last 30 years. Some important ones are in Chota Udaipur (Rajasthan), Kotari Seed Bank, Ranchi (Jharkhand), and a seed bank near Meerut (Uttar Pradesh) [48]. *Sahaja Samrudha* established a community seed bank in Mandya district for rice folk varieties and a *Malangi* Seed Bank in Periyapatna taluk (Mysuru district) in Karnataka for its native varieties (Sahajasamrudha.org). Similarly, the Centre for Interdisciplinary Studies (CIS) established a community seed bank in 1997 named *'Vrihi Beej Binimoy Kendra'*, which is the largest folk rice seed bank in eastern India and is rooted in the Rayagada district of Odisha with the help of the Navdanya Foundation. [49]. M.S. Swaminathan Research Foundation (MSSRF) established a community seed bank in Kolli Hills (Tamil Nadu) for local landrace diversity conservation and distribution and three seed banks in 47 villages to allow farmers to store, exchange, and access high-quality seeds in Koraput (Odisha) (mssrf.org). Shrestha et al*.* [47] highlight that the roles and responsibilities of members in seed saving initiatives are to be in accordance with the needs of the community and in keeping with the regional context, customs, and values. The importance of local donations for physical infrastructure and conservation efforts combined with income-generating endeavors resulted in the sustainable operation of the CSBs. Further, policy interventions by government institutions and financial help from different sources act as catalysts for the sustainable growth of the CSBs.

4.3 Stakeholders' Concept

Crucial to the management of landrace conservation are major stakeholders in on-farm conservation, including farmers, farmer communities (including tribal), and non-governmental organizations (NGOs). Farmers and farming communities have been actively involved in the conservation and cultivation of landraces, or traditional crop varieties, that are well-suited to their particular local environment for a number of generations. In their role as custodians, farmers have been preserving the genetic diversity of landraces through sustainable indigenous management practices.

4.3.1 Role of custodian farmers in on-farm conservation

Recognizing and assisting individual farmers who contribute exceptionally to on-farm conservation—known as custodian farmers and their communities—is another strategy to bolster on-farm conservation [37]. All the farmers are *de facto* conservationists of crop diversity, since the selection and preservation of seeds and planting material are fundamental components of agricultural life [50]. However, a few farmers consistently make a name for themselves in their communities by cultivating an exceptional diversity of crops, including rare and endangered varieties, and by possessing a wealth of traditional plant knowledge [3,51,39]. These exceptional farmers have been given many names, including barefoot botanists, seed experts, nodal farmers, seed curators, conservationists, seed keepers, and custodian farmers, as we shall refer to them in this article [50,46,51]. Since most of the custodians are strong leaders in the community beyond on-farm conservation activities, especially agricultural activities [37]. Their leadership positions reflect their commitment to the conservation work that needs to be recognized and shared with a greater number of people.

There are studies in India that illustrate the custodian farmers' motivations, which can come from a variety of sources, including personal, social, economic, cultural, environmental, and policy/legal concerns, all of which influence how they farm to differing degrees [39]. Gajanana et al*.* [52] identified the key forces behind sustaining a rich diversity in Mango as sentiment towards ancestors' resources, income, variety of fruits, and cultural and personal hobbies for local diversity in different parts of India, viz., Malihabad (Uttar Pradesh), Sirsi (Karnataka), Chittoor (Andhra Pradesh), and Pusa (Bihar). Gautam et al*.* [53] surveyed the Andaman-Nicobar group of islands (A & N islands), a storehouse of plant biodiversity, to document custodian farmers and their on-farm conservation

activities. Their record contains a list of custodian farmers and their contribution to conserving the economically important plant and animal genetic resources of the A & N islands. As a part of the UNEP/GEF project entitled "Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihoods, Food Security, and Ecosystem Services," implemented in 36 rural communities in India, Indonesia, Malaysia, and Thailand. Sthapit et al. [39] documented a few instances of custodian farmers' on-farm activities in India as well. The report highlighted the role of custodian farmers in preserving, adapting, and disseminating the landrace diversity of different tropical fruits to fellow farmers and other community members.

Custodian farmers are identified for their conservation activities and are being awarded "Plant Genome Savior Farmer Recognition" by PPVFRA for their vital role in conservation and promotion of indigenous crop cultivars [41]. Gajanana et al. [52] also stressed the same for the identification of custodians and extending support to them as a strategy for conserving diversity. Since then, these farmers have maintained the diversity without any formal support for generations.

4.3.2 Role of local communities (farming communities and tribal communities)

Communities as a whole make a substantial contribution to landrace management and conservation. Because landraces are so strongly connected to local customs and traditions, farming communities view them as vital components of their cultural heritage in addition to genetic resources. Landraces are frequently preserved and promoted through social interactions, rituals, and a sense of collective identity. This shared accountability of traditional seed systems encourages a sense of ownership and a dedication to preserving landraces and associated knowledge which strengthens landraces and makes them more resilient [54]. According to Subedi [46], communities play a crucial role in preserving regional seed networks, which facilitate the exchange of landrace seeds both within and between farming communities. These systems, which rely on long-standing traditions of bartering, sharing, and seed preservation, maintain the diversity and adaptability of landraces. Diversity fairs are another concept adopted, especially by tribal communities, to showcase their diversity as a marketing platform that plays a crucial role in seed dissemination and exchange in the region.

Landrace conservation by local communities is a critical and sustainable approach to preserving traditional crop varieties and agricultural practices. It is emphasized in many illustrations in the Indian framework. A case study by Thamizoli and Pisupati [55] about community conservation in Jawhar block of Palghar district in Maharashtra named "The Seed Saver Farmers Group". The community focuses on crops like rice, finger millet, little millet, black gram, hyacinth bean, and some local vegetables. Preservation of all these crop cultivars is done by establishing 12 *in situ* conservation centers in 10 villages and through kitchen gardens. It is BAIF's community-led approach to conservation and management of native crop cultivars. It primarily focuses on conservation through use by involving communities and establishing community seed saver networks and seed production is a key activity in this program. Additionally, it emphasizes the value of scientific methods and community knowledge, which opens up a lot of possibilities for the promotion and selection of exceptional crop cultivars from accessions that have been gathered and preserved.

Community seed conservation activities were found to be present throughout the length and breadth of the country wherever the possibility of native seed or landrace availability was identified. In some cases, farmers themselves, or with the help of some organizations, establish farming communities. *Siddharudha Savayava Krushikara Balaga*, Belagavi (Karnataka); *Pokkali* Rice Farming Community (*Kadamakkudy-Varappuzha Jaiva Pokkali* ICS), Ernakulam, Kerala; *"Yaha Mogi Mata Sthanik Biyane Sanvardhan Samiti",* Dhadgaon, Tribal block of Nandurbar District, Maharashtra, to mention a few, and many such communities are present all over India.

Community conservation activities are being identified and awarded the "Plant Genome Savior Community Award" by PPVFRA for their immense activity in conservation and promotion of indigenous crop cultivars [41]. This formal recognition of communities has inspired many other communities to revive, conserve, and promote the diversity of indigenous cultivars.

4.3.3 Non-governmental organizations (NGOs)

These are institutions crucial for the management and protection of landraces. These

organizations are regularly involved in assisting farmers and their communities to save and promote native seeds. To enhance the capabilities of farmers for sustainable conservation of landraces, NGOs offer technical assistance, resources, seeds, and training. Additionally, through promoting information and knowledge sharing between various communities and geographical areas, NGOs support best practices and cutting-edge approaches for landrace conservation. They act as intermediaries, creating links between custodian farmers and scientists, researchers, and decision-makers to bridge the gap between conventional thinking and scientific advancements.

Navdanya, MSSRF, Sahaja Samrudda, Green Foundation, BAIF, Annadana Seed and Soil Savers, etc. are some of the NGOs and associations active in the area of community seed exchange and germplasm conservation in different states of the country. They have been involved in setting up community seed banks, providing seeds of native crops from different region, and helping to establish kitchen gardens by providing indigenous seeds of various vegetables [44]. Through more funding and improved scientific support, NGOs can become potential players in the field of on-farm conservation activities across the country.

5. DOCUMENTATION OF CASE STUDIES

Unfortunately, the diversity of local crops and their wild relatives is being lost at an alarming pace as a result of changing markets, farming practices, environmental degradation, and many other factors. Often, they are lost even before they are completely documented, and certainly before they have been studied by formal research, leading to their name, 'neglected and underutilized species'. On-farm conservation can be better understood by documenting the material in the context of agriculture, traditional knowledge, and food systems [56].

Researchers have been documenting the state of on-farm conservation initiatives in various parts of the world [39,36,57]. As India is a rich biodiverse country and agriculture diversity is present in almost all the states, so is on-farm conservation. Some instances of on-farm conservation of landrace availability have been recorded in various states, as provided in Table 1. Landraces developed in the farmers' fields over generations and centuries are the on-farm genetic materials that are regarded as the repositories of important traits as well as champions of conservation agriculture and have scope for new market opportunities.

Table 1. Some documented on-farm conservation related activities in different states

S. No.	State	Crops	References
1	Andaman & Nicobar Islands	Multiple crops	Gautam et al. [53].
2	Andhra Pradesh	Cereals and Millets	Pandravada et al. [11]
3	Arunachal Pradesh	Rice	Wangpan et al. [58]
		Rice	Longvah and Prasad [23]
4	Assam	Rice	Das and Das [7]
5	Chhattisgarh	Rice	Rathi et al. [9]
6	Goa	Horticultural crops	Maneesha et al. [45],
7	Himachal Pradesh	Multiple crops	Rana et al. [40]
8	Jharkhand	Rice	Dikshit et al. [59]
9	Karnataka	Rice	Hanamaratti et al. [26]
		Rice	Rajanna et al. [60]
		Mango	Gajanana et al. [52]
		Tuber crops	Asha et al. [28]
10	Kerala	Rice	Latha et al. [61]
11	Maharashtra	Vegetables	Khan and Kakde [62]
		Multiple crops	Patil et al. [31]
12	Madhya Pradesh	Kodo millet	Joshi et al. [63]
		Rice	Kujur et al. [64]
		Custard Apple	Goutam et al. [25]
13	Nagaland	Rice	Roy et al. [24]
		Rice	Roy et al. [34]

S. No.	State	Crops	References
14	Odisha	Rice	Mishra et al. [33]
		Rice	Logapriyan et al. [65]
15	Rajasthan	Pearl millet	Yadav [66]
		Multiple crops	Malik et al. [54]
16	Tamil Nadu	Rice and	Vijayalakshmi and Arumugasamy [14]
		Vegetables	Sridhar and Subramanian [44]
		Vegetables	Takeshima and Nagarajan [10]
		Minor millets	Priyanga et al. [67]
		Rice	Bhuvaneswari [38]
		Rice	
17	Uttar Pradesh	Sorghum	Elangovan and Babu [68]
		Mango	Rajan et al. [42]
18	Uttarakhand	Multiple crops	Bisht et al. [56]
		Multiple crops	Nautiyal et al. [30]
		Rice	Mehta et al. [12]
		Multiple crops	Gururani et al. [69]
19	West Bengal	Rice	Deb [70]
		Rice	Deb and Malhotra [32]
		Rice	Chakravorty and Ghosh [8]
		Rice	Adak et al. [20]
20	Multiple states	Multiple crops	Sthapit et al. [39]
			Jayabalan et al. [22]

6. POLICY AND INSTITUTIONAL SUPPORT

The National Biodiversity Authority was established in India in 2002 to address the demands of the Convention on Biological Diversity (CBD) on a national scale and to establish policies and regulations governing the use of biodiversity resources throughout the nation. The National Bureau of Plant Genetic Resources is an organization that works on PGR collection and documentation. It also offers technical instructions for on-farm conservation efforts and access to genetic resources that have been conserved. However, by giving out prizes and offering financial support, PPVFRA is honoring the efforts of farmers and farming communities in the preservation of priceless on-farm resources [41].

Without enough information on the location, diversity, and accessibility of landraces, it is difficult for scientists and plant breeders to effectively utilize the particular traits of interest found in them. As a result, a platform for storing information on PGR conservation on farms, conservation goals, resistance sources, adaptive potential, and cultural significance of the preserved genetic resources is required. For the benefit of scientists, researchers, and environmentalists, this data needs to be available to the general public. PGR informatics has gained prominence due to the growing importance of PGR conservation and exploitation on the one hand and technological breakthroughs in computer science for data management and digitization on the other. PGR informatics is the generation, storage, retrieval, and presentation of many types of information, as well as its analysis, discovery, exploration, and extraction [71]. In order to support future data collection and recording of on-farm conservation efforts, a comprehensive set of landrace descriptors and a database for information management must be established.

7. CONCLUSION AND FUTURE PROSPECTS

7.1 Prospects for the Effective Management of On-Farm Conservation Activities in the Future

It is essential to work with indigenous groups to conserve on-farm genetic resources through on-farm conservation. Participating in conservation initiatives on an active basis will protect these people's traditional knowledge, promote sustainable farming methods, and increase the resilience of local agricultural systems [34]. Maintaining conventional farming and tribal practices can benefit future generations by aiding in the preservation and evolution of landraces as well as helping them adapt to shifting weather patterns and temperatures [33].

- Demand for vegetable seeds for kitchen gardens and terrace gardens is increasing, so strengthening women-led enterprises for the production and marketing of vegetable seeds should be promoted [38].
- Quality seed production and large-scale promotion among the community members help promote native varieties.
- Organizing field training on organic input production and community-level seed production
- Organizing seed exhibitions in the respective regions for the promotion of worthy crop landraces and for the sale of produce.
- Organizing food festivals and diversity fairs in cities and towns for market promotion of indigenous produce.
- It has been suggested that the demand for crop landraces and their derived products (value-added products) may be expanded through improved markets that promote consumers' awareness and policy support.
- Value and reward farmers' individual and collective efforts to safeguard agricultural biodiversity and associated cultural values and knowledge.
- Support farmers technically and financially to organize themselves, exchange knowledge and experiences, and strengthen their organizational capacity [72-76].

7.2 Conclusion

Farmers have a crucial strategic role in preserving the variety of crops grown worldwide. Despite the fact that on-farm diversity is significantly larger and more diversified than that of *ex situ* techniques, research and development efforts to address on-farm conservation are inadequate, and national conservation programs do not adequately incorporate it. Therefore, surveys are necessary, and reliable documentation might bring insight into farm operations and how they contribute to the preservation of genetic resources. To identify them and provide outside support, the roles of important players and strategies-such as custodian farmers, communities, local seed banks, and kitchen gardens-must be mainstreamed. Therefore, it is essential that we pay more attention to acknowledging farmers' contributions to on-farm conservation and developing strategies and tactics to help them in their endeavors.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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